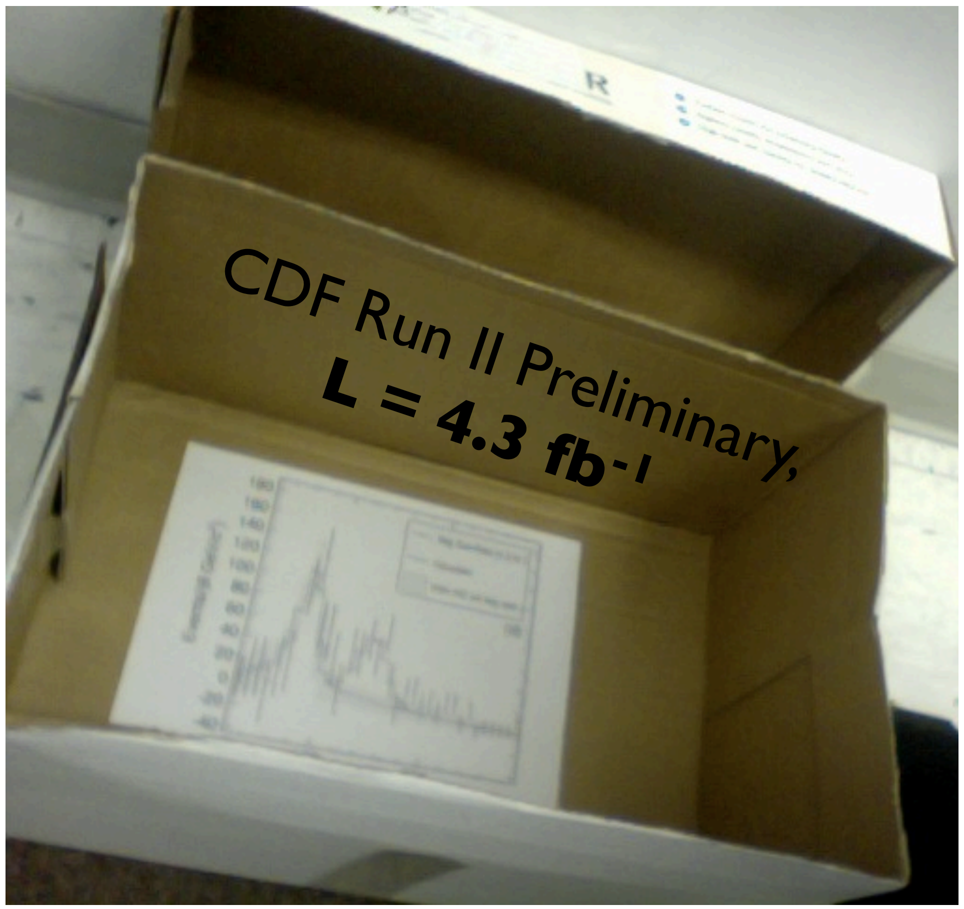
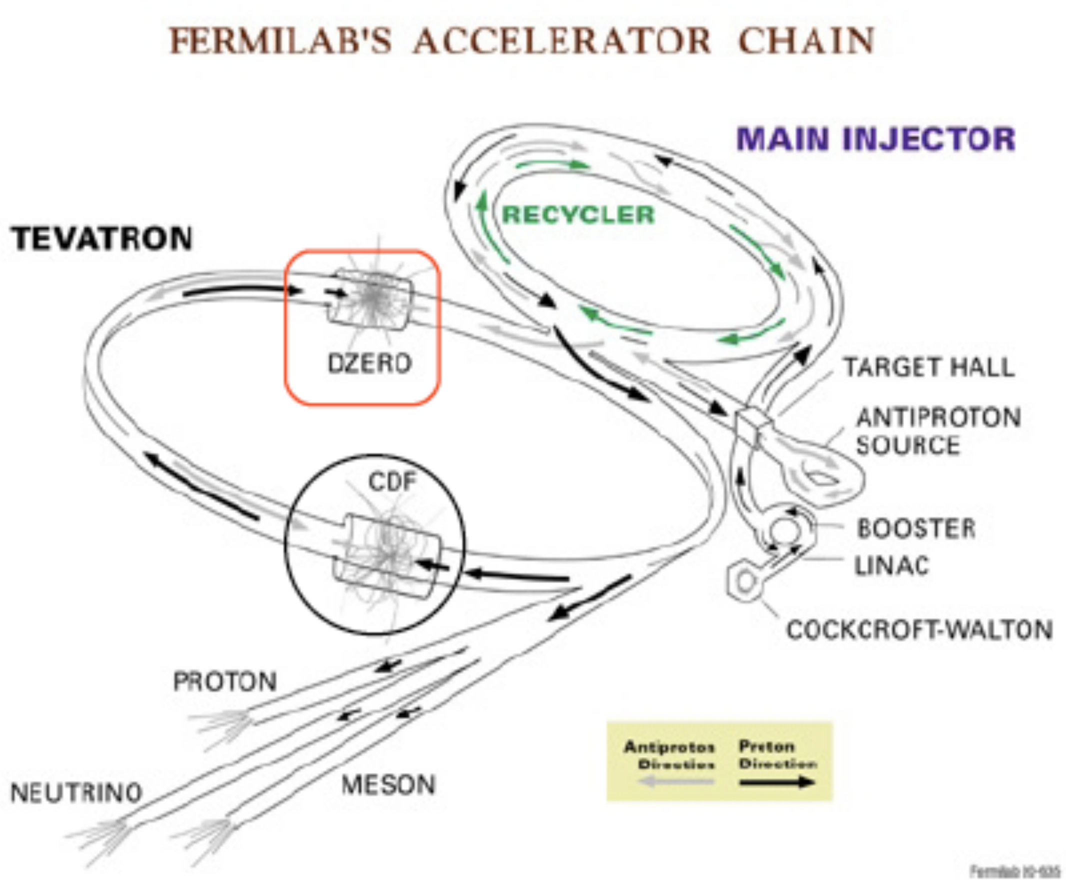
Update on dijet mass spectrum in W + 2jets events @ CDF



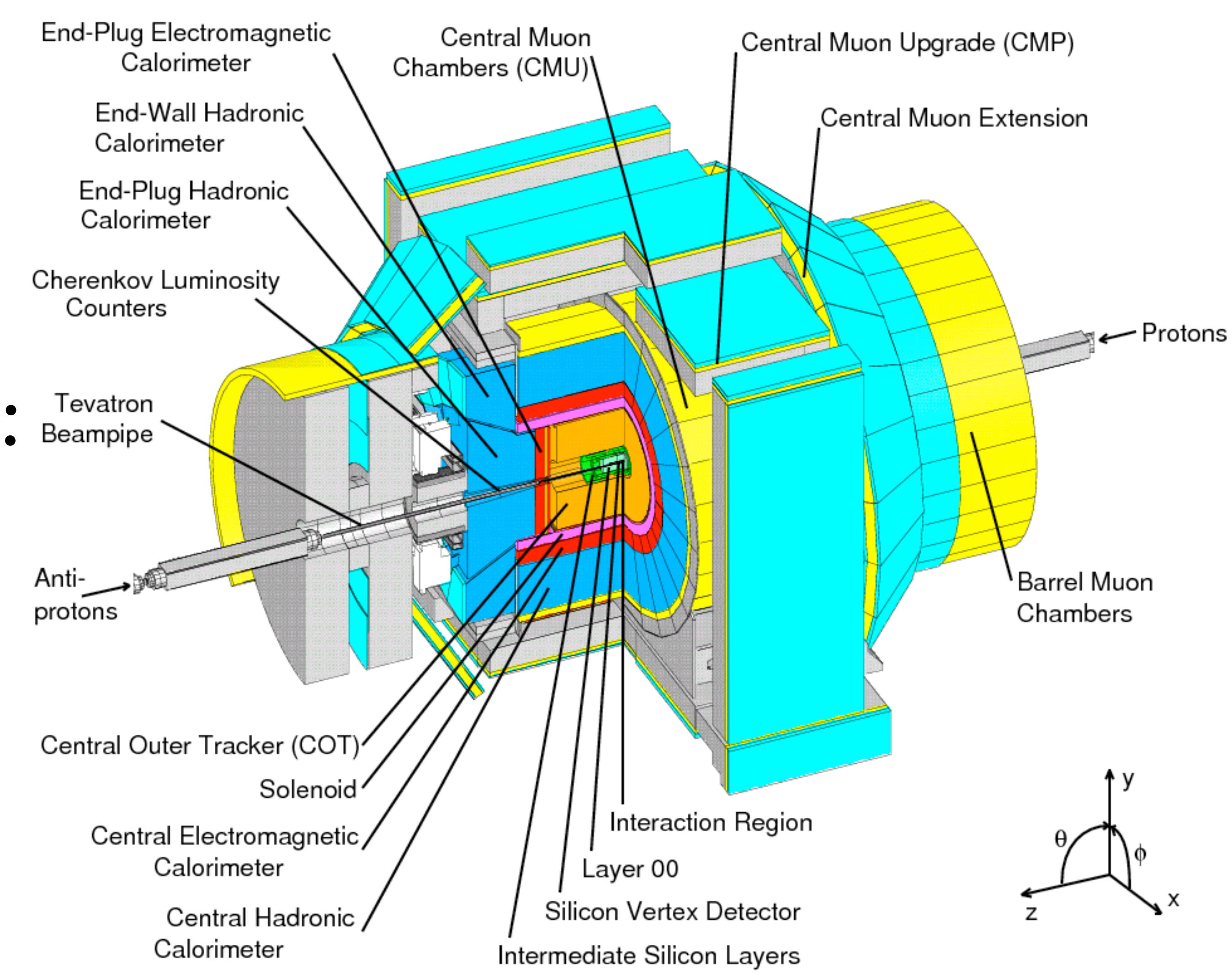
M. Trovato
(Scuola Normale Superiore - Pisa & Fermilab)

Experimental environment



- Ppbar collisions at 1.96 TeV (2001-2011)
- Delivered ~12 fb^{-1} integrated luminosity (~10 fb^{-1} acquired by CDF)

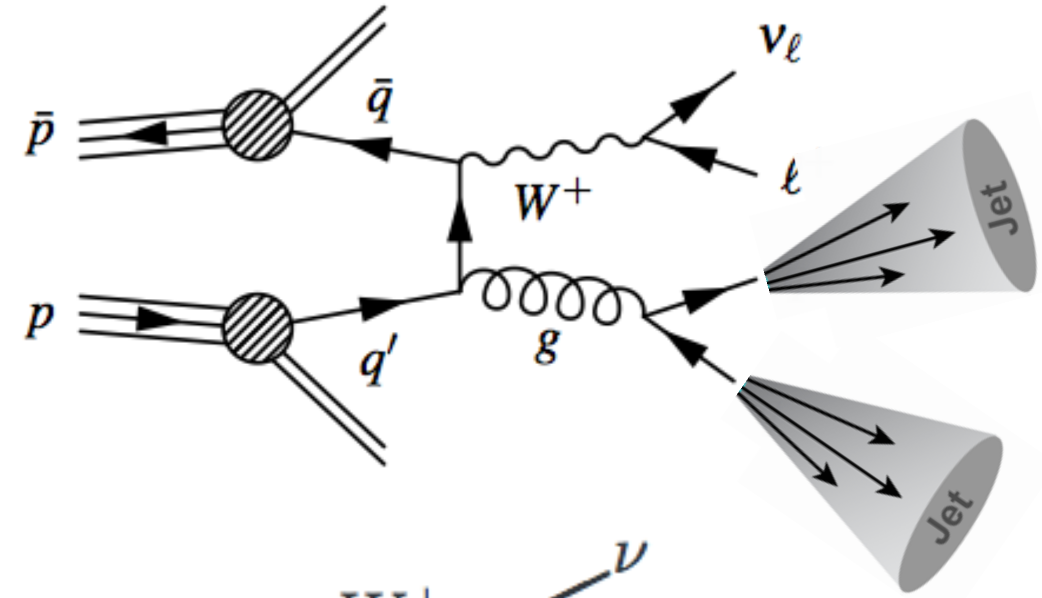
- CDF II: multipurpose detector:
  - Excellent tracking system with Silicon
  - Electromagnetic and hadronic calorimeters
  - Muon chambers

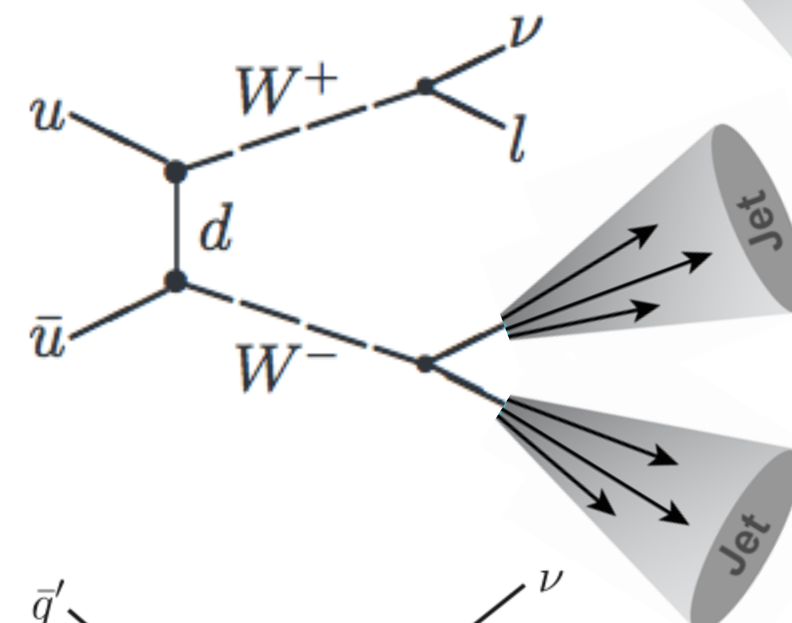


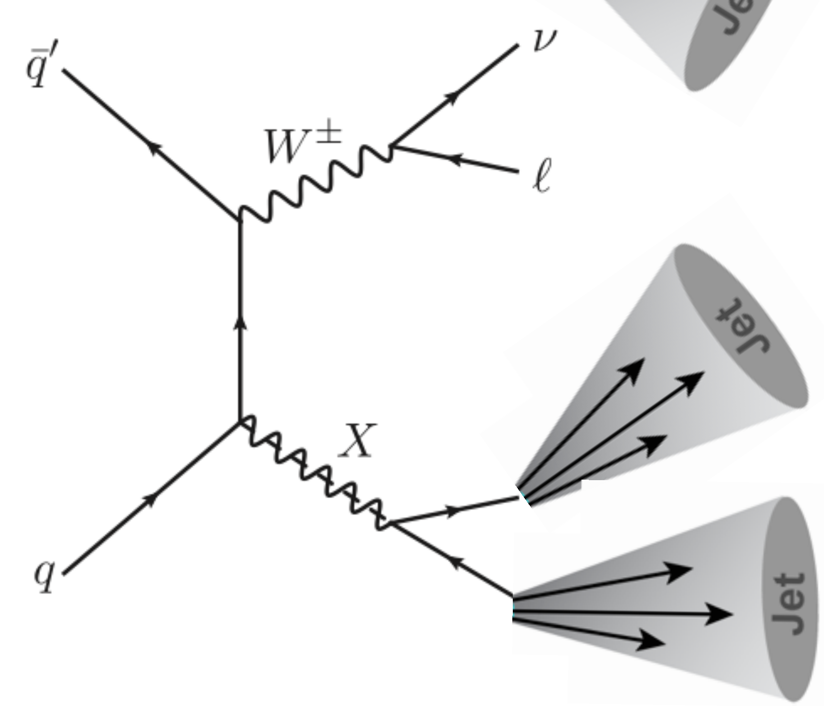
Motivation

- Measurement of associated production of W bosons and jets is a <u>important test of the standard model (SM)</u>

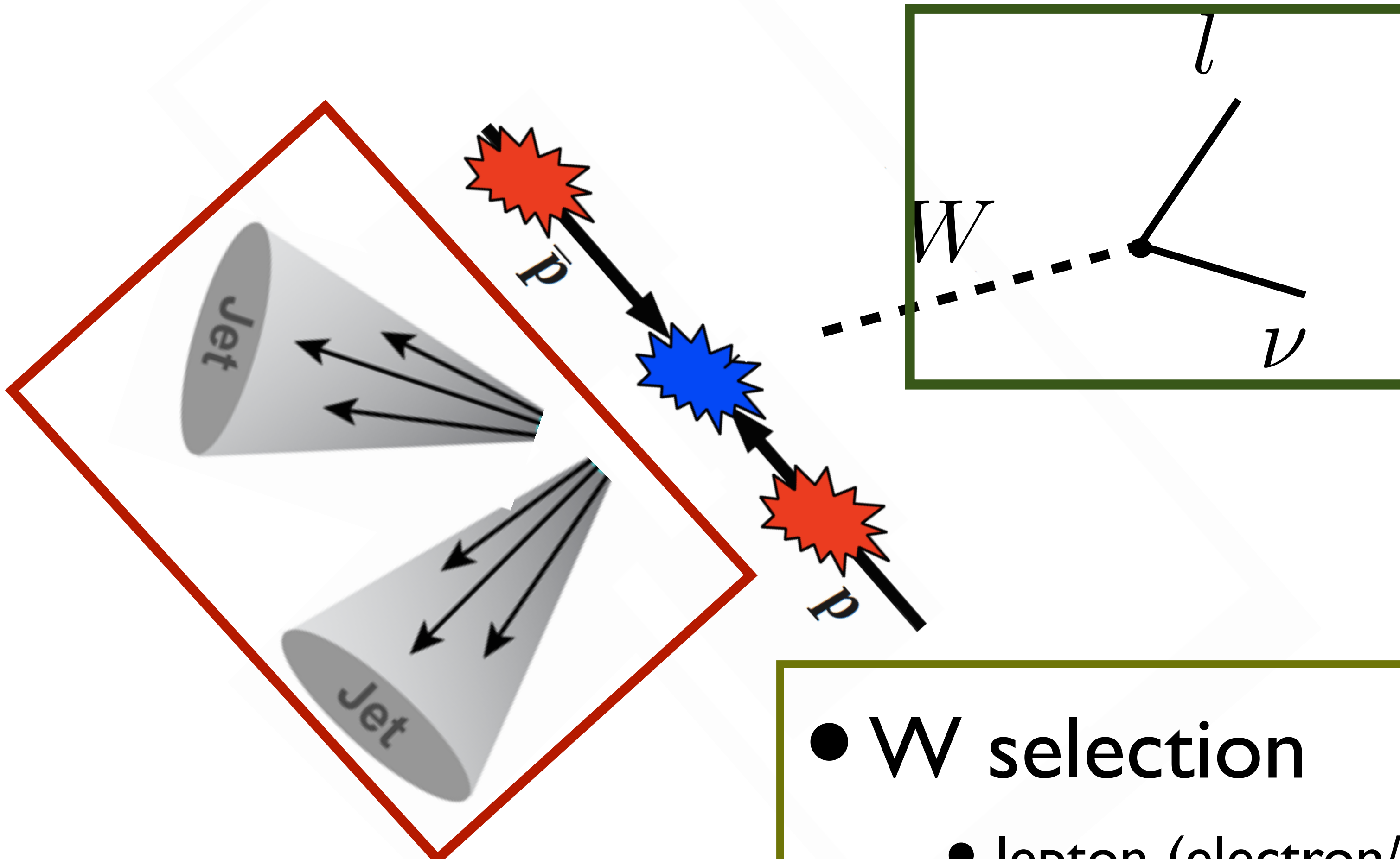
- W+jets production is:
  - ❖ a dominant background for important processes being studied at the Tevatron
    - Diboson, Single-top, Higgs, etc.
  - ❖ a background in searches for new physics beyond SM ("X")







Event selection: revisit the old result



- W selection
  - lepton (electron/muon) P_T>20 GeV, |η|<1
  - $\not{E}_T$ >25 GeV
  - M_T^W > 30 GeV

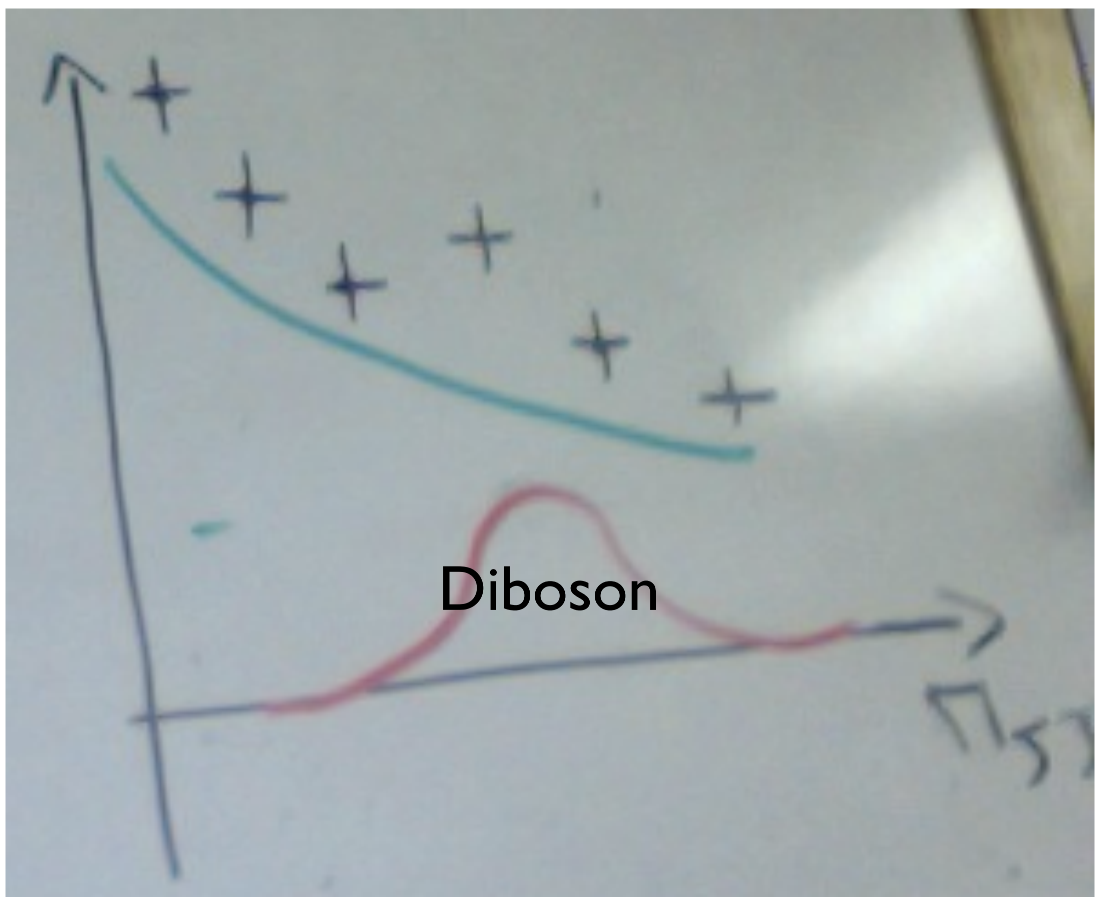
- Dijet Selection
  - Two jets ("jet1","jet2") each with:
    - E_T>30 GeV, |η|<2.4
    - No other jets passing these criteria

- Additional cuts
  - P_T(jet1,jet2)>40 GeV,
  - |Δη(jet1,jet2)|<2.5
  - Δφ($\not{E}_T$,jet1)>0.4

Modeling of the data sample

How do we model the data?

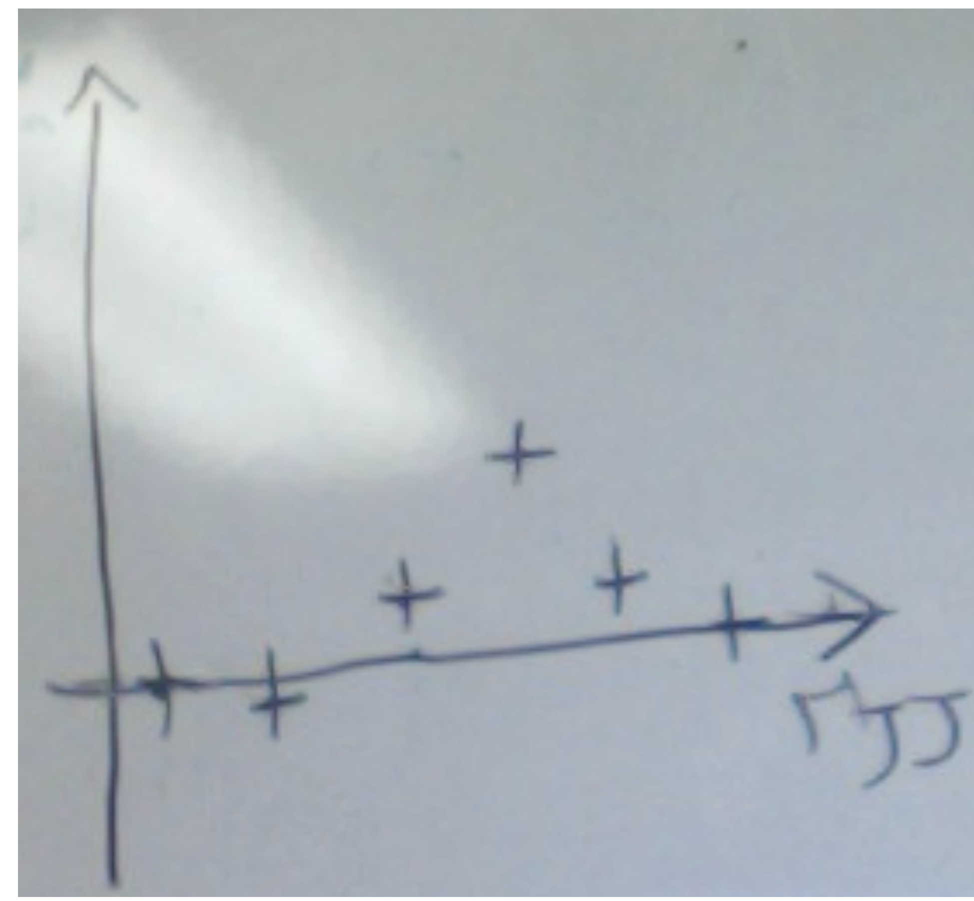
Fit in dijet-mass ("Mjj")



After the fit

Data-SM

(excluding Diboson)

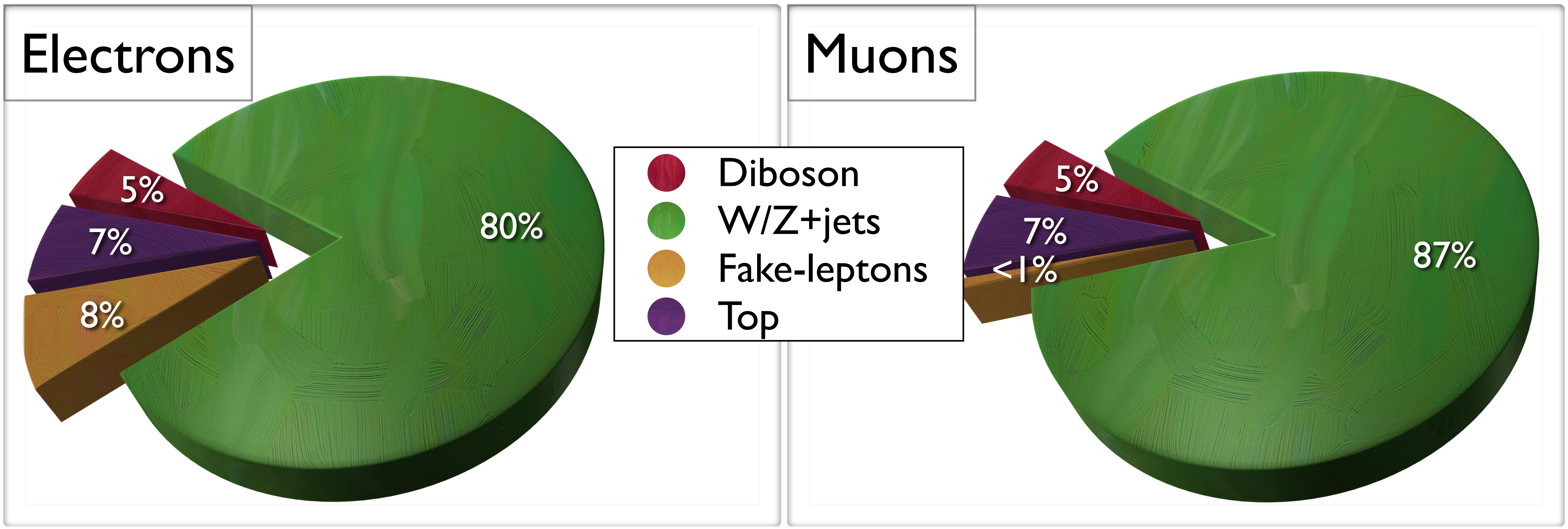


Modeling the data sample

Process	Shapes	Rate constraint
$WW/WZ/ZZ$ inclusive	PYTHIA	Theory
$t\bar{t}$	PYTHIA	Measured cross-section
single-top	MadEvent+PYTHIA	Theory
$Z \to e, \mu, \tau$+jets	ALPGEN+PYTHIA	None
W+jets	ALPGEN+PYTHIA	None
Fake leptons from multi-jets	from data	from data

PYTHIA oracle

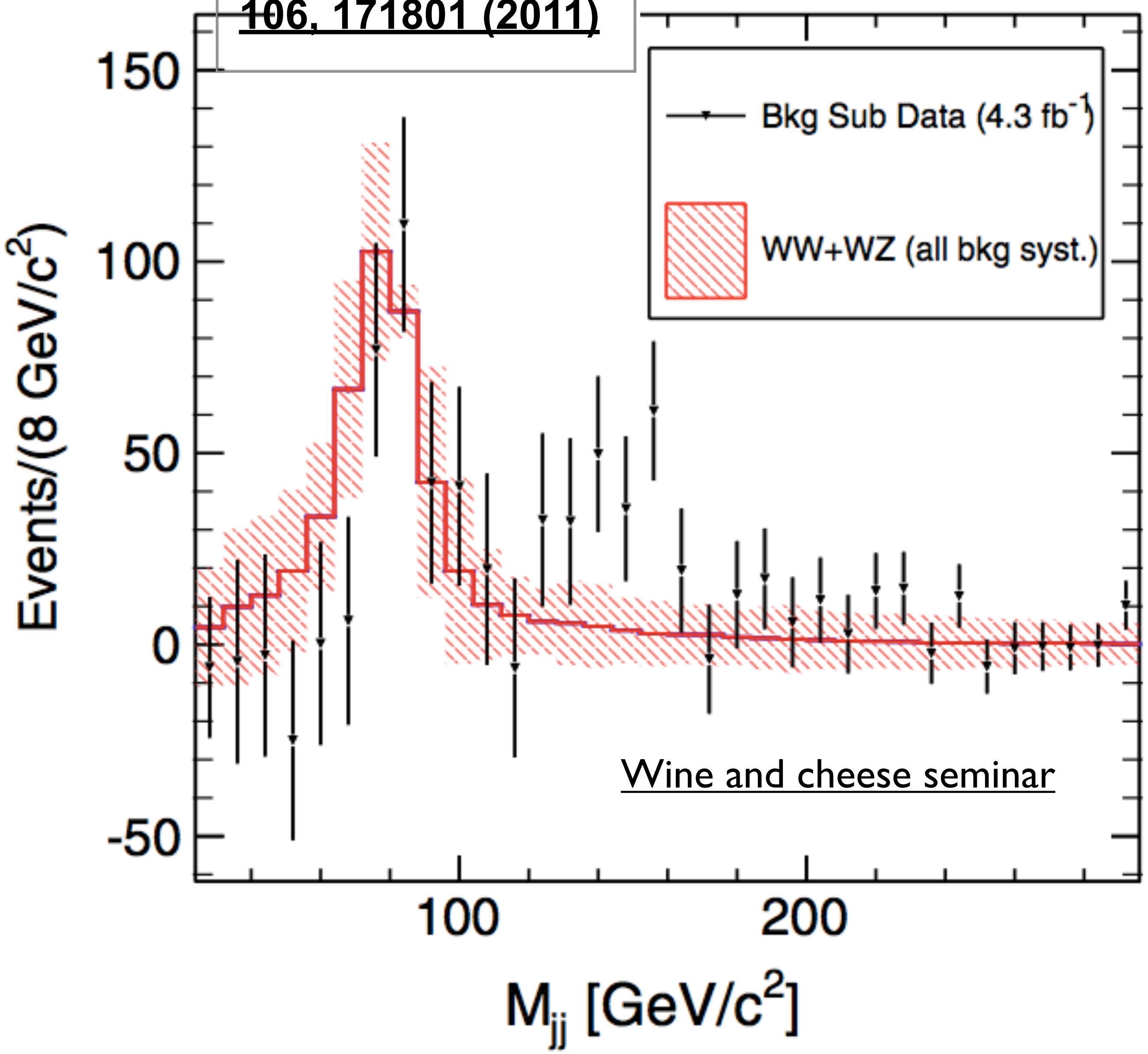
Composition of the data sample



Previous result

- CDF has reported an excess of events around a dijet mass of 145 GeV using a 4.3/fb dataset. We stated that "such an excess is not described by current theoretical predictions within the statistical and systematic uncertainties"

Phys. Rev. Lett. 106, 171801 (2011)

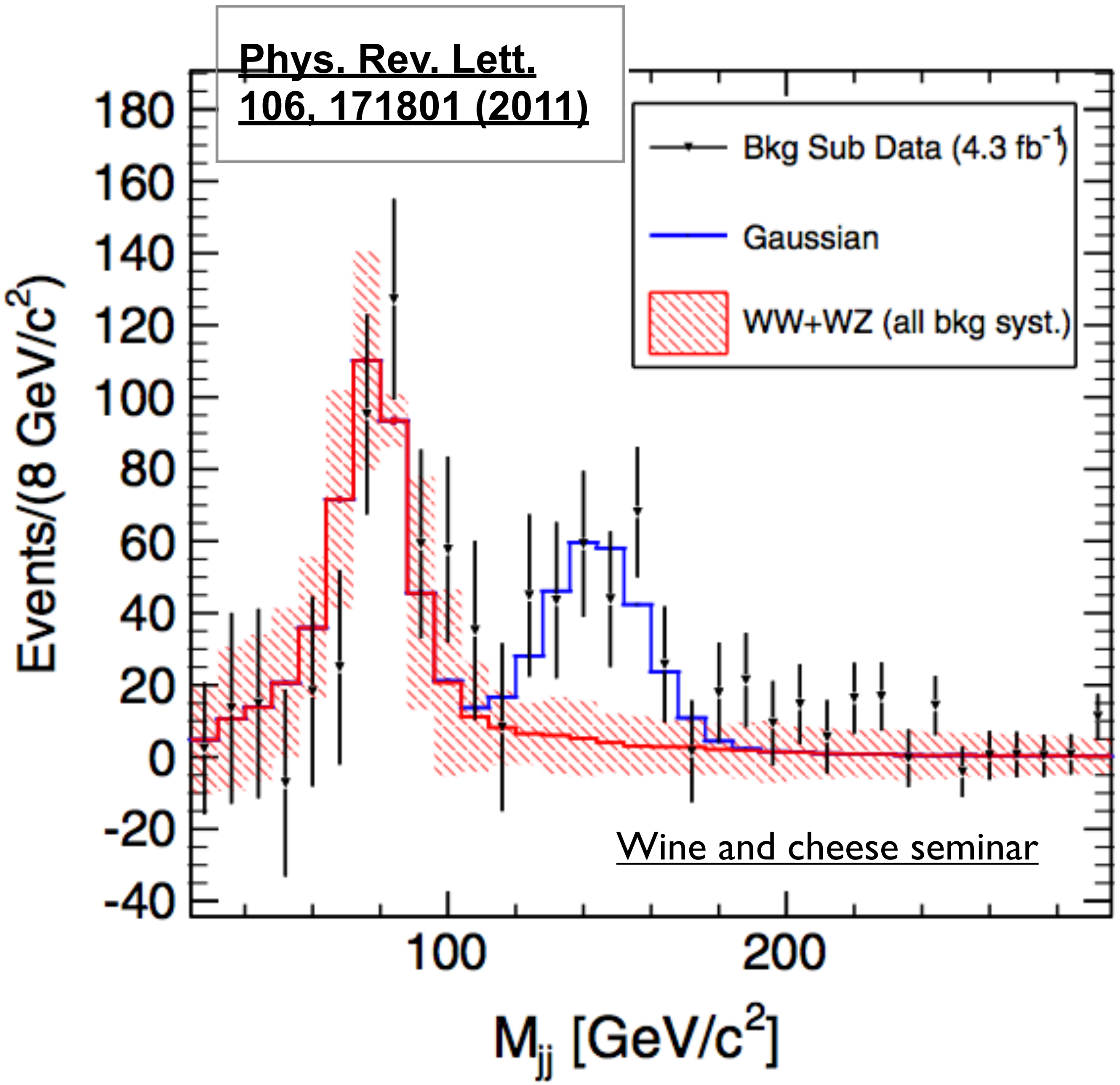


Wine and cheese seminar

Previous result

2/2

- "One possible way to interpret this disagreement is a gaussian contribution in the 120–160 GeV/c^2 mass range" with the significance of 3.2 σ

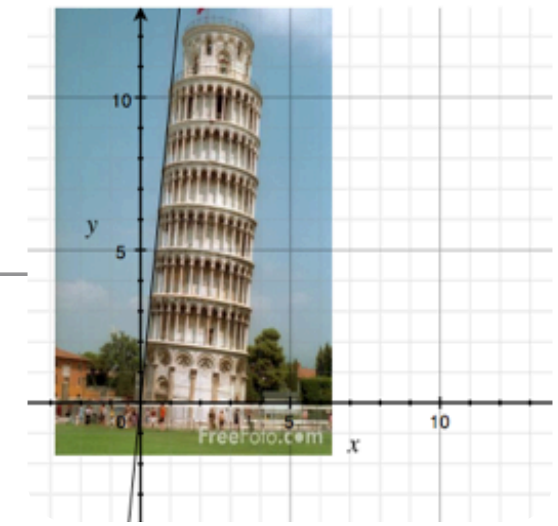


Where we are today

- Reproducing the same analysis with the full CDF dataset we observe a similar excess with even higher significance
- However, we are aware that other experiments do not observe the same excess
- What's going on?

Moving on

- In the past two years we studied the W+2jets sample intensively, exploring New Physics models, but also searching for possible **deficiencies in our SM predictions**

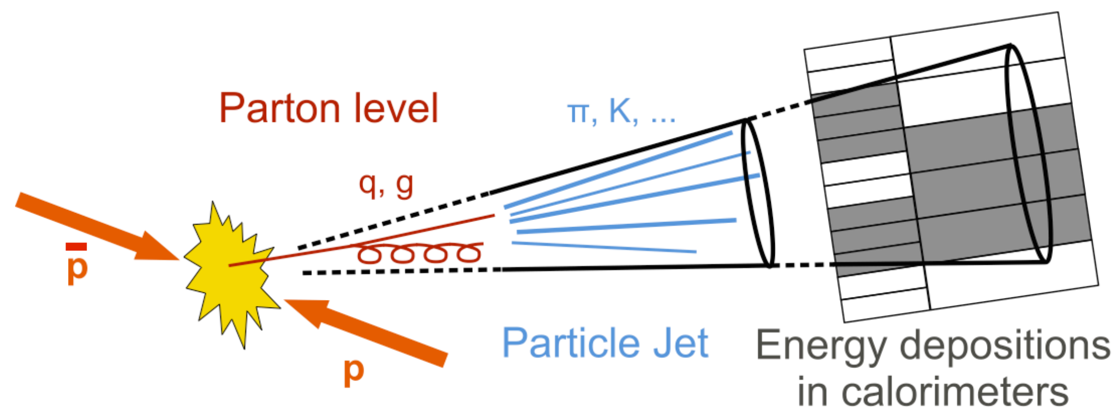


- Here we focus on the two issues found to be most relevant:
  - Modeling of the jet response
  - Modeling of the fake-leptons
- We further reject events with low dijet opening angle since predictions do not model accurately the data in that region
  - minor effect at dijet masses > ~50 GeV/c^2
- All the details about our studies will be published soon

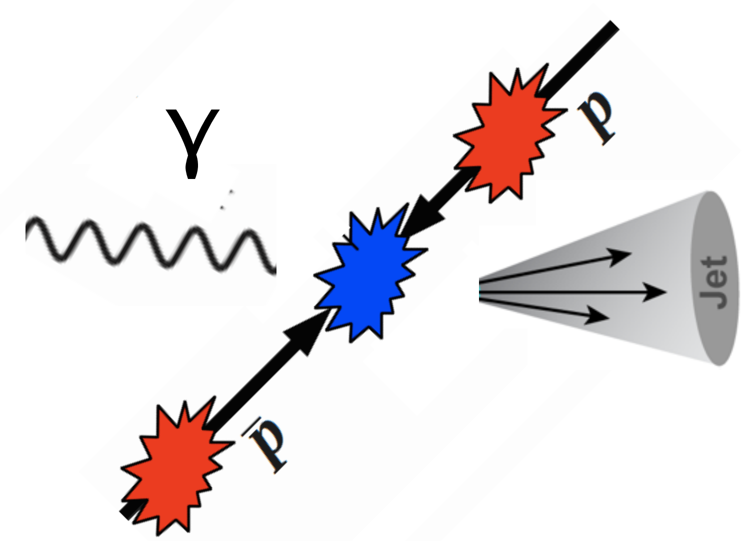
- Modeling of the jet response
- Modeling of the fake-leptons

Object identifications - jets

- Jets of particles:
  - collection of calorimeter towers clustered with the "JETCLU" cone algorithm (radius R=0.4)

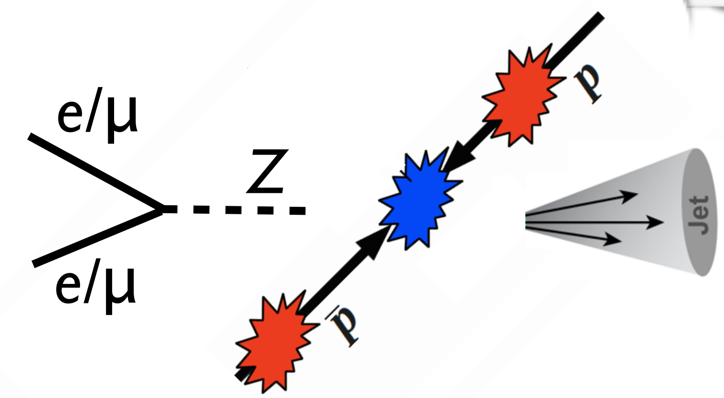


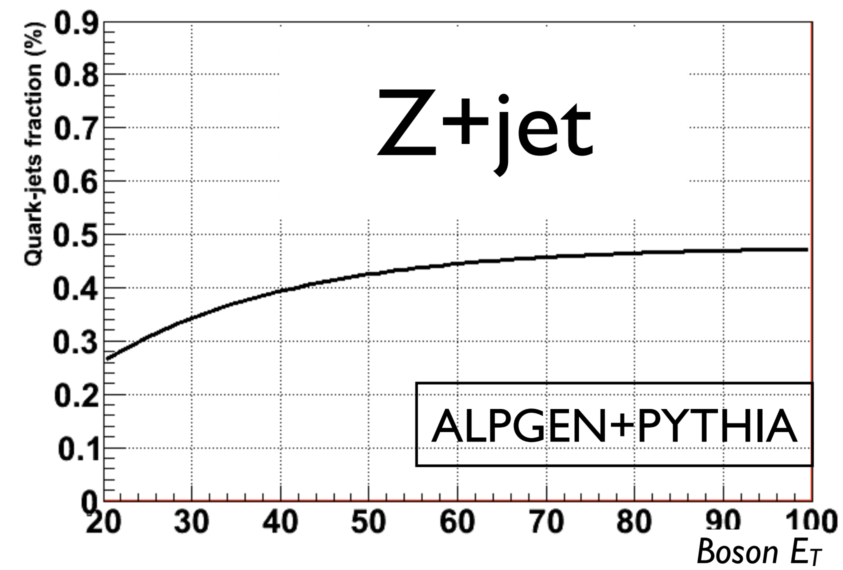
- Jet energy scale ("JES")
  - Transfer function from the tower-cluster to the hadron-level energies (true energy)
  - Validated in γ+jet events:
    - γ+jet events are quark dominated (>70% at E^{γ}_{T}<80 GeV)

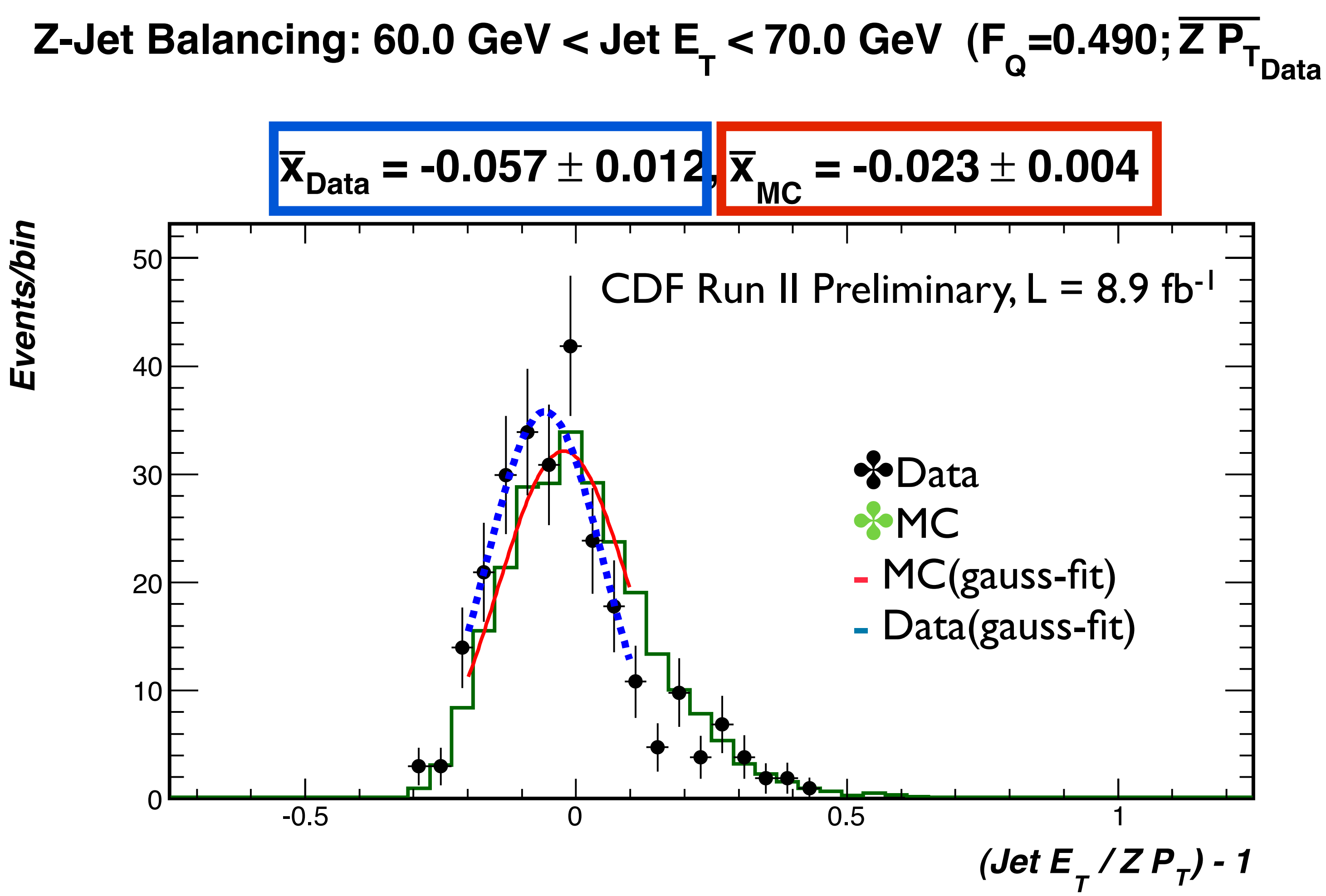


NEW Object identifications - jets

- But, when checking the JES in a gluon-dominated sample (Z+jets), we find a problem







ALPGEN+PYTHIA **MC** and **Data** are **not compatible**

NEW

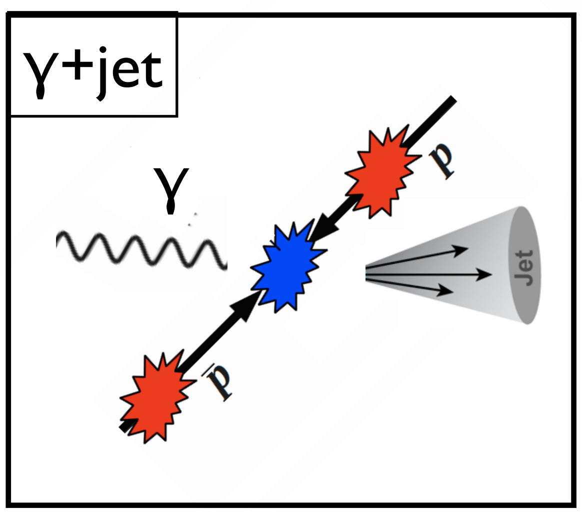
Object identifications - jets

3/4

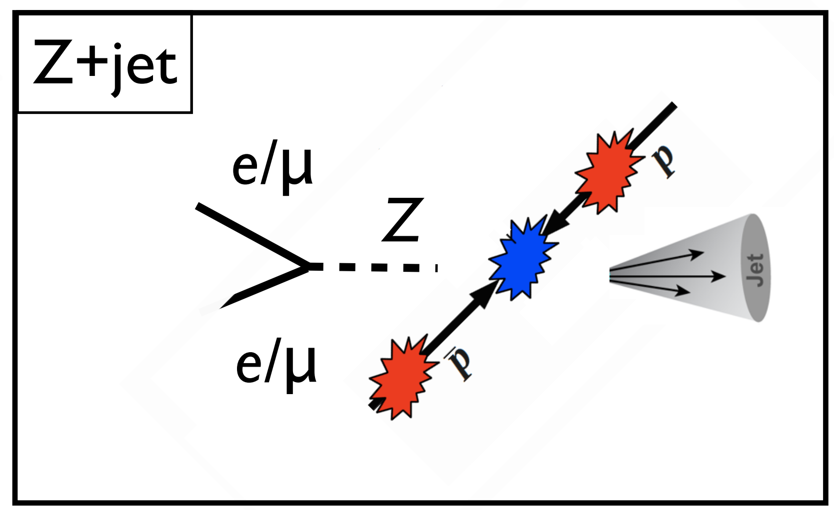
NEW

Object identifications - jets

jet balancing



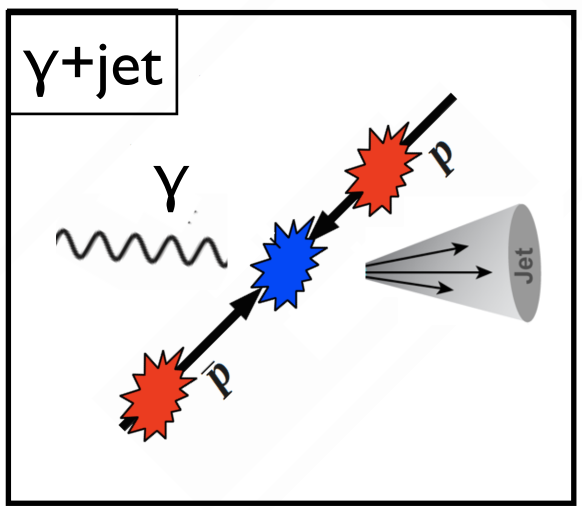
,



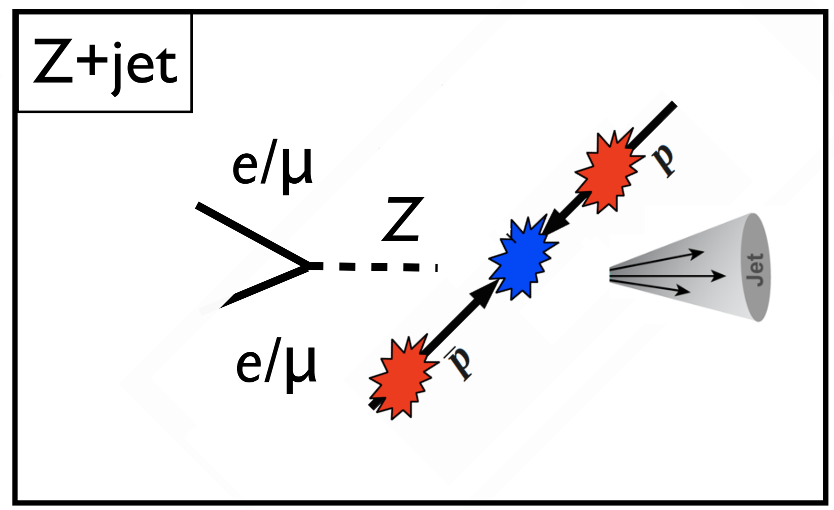
NEW

Object identifications - jets

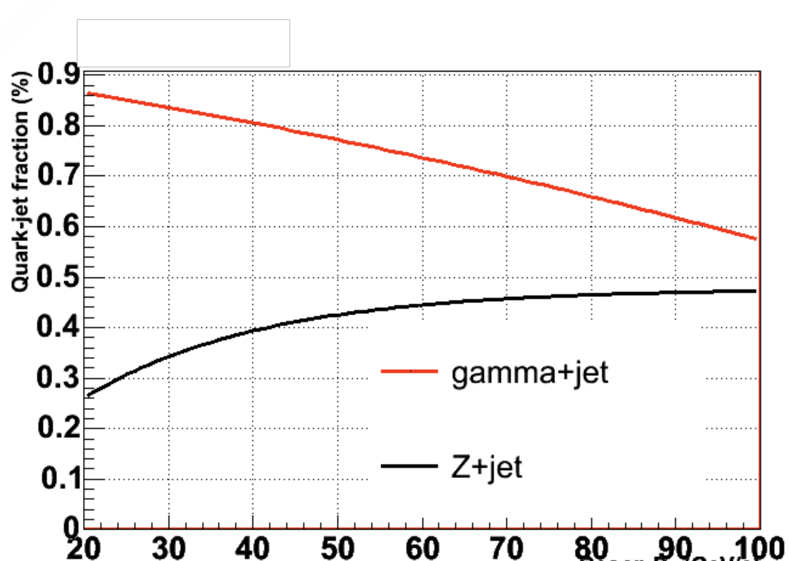
jet balancing



,



Quark-jet fraction (from MC)

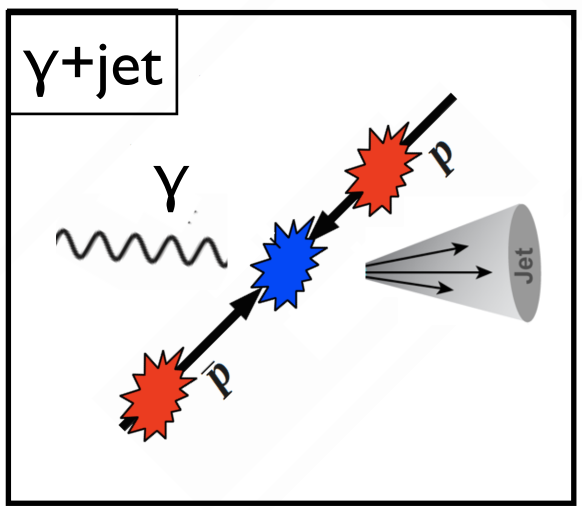


, (cross-checked with data)

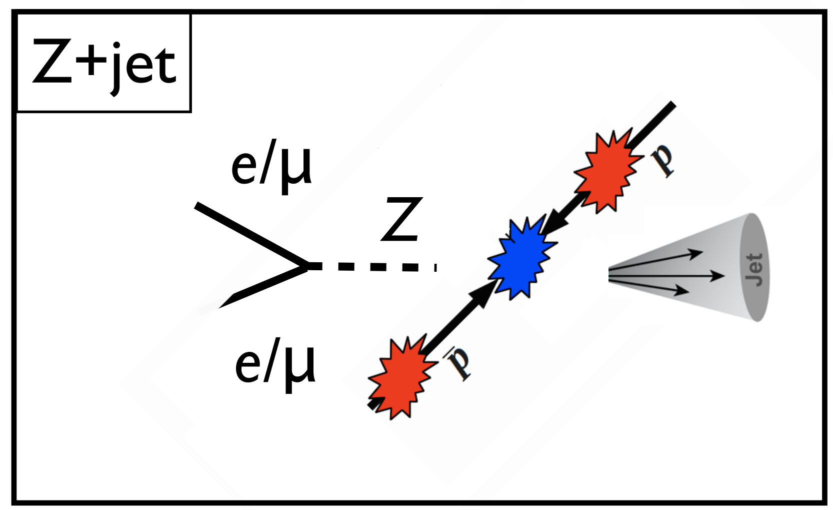
Object identifications - jets

We will make the assumption that the observed discrepancies between γ+jet and Z+jet originate from differences in the modeling of the jet response for quarks and gluons

jet balancing

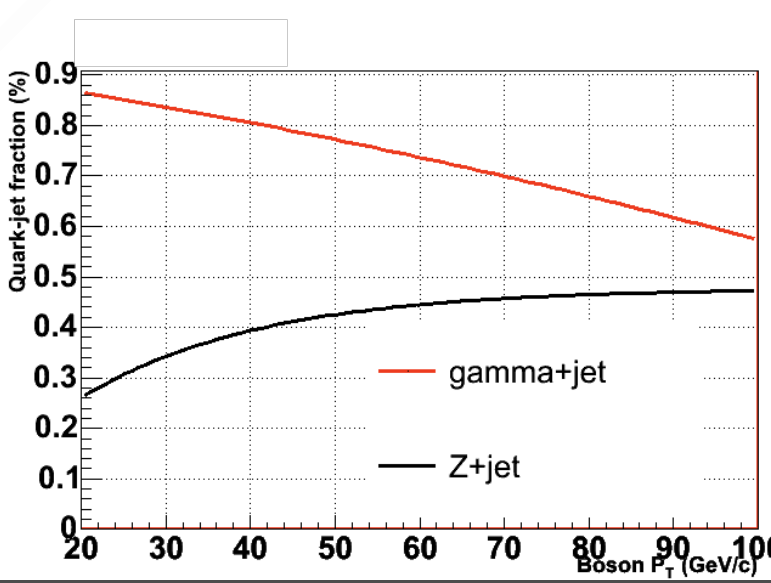


,



I Got It! :

Quark-jet fraction (from MC)



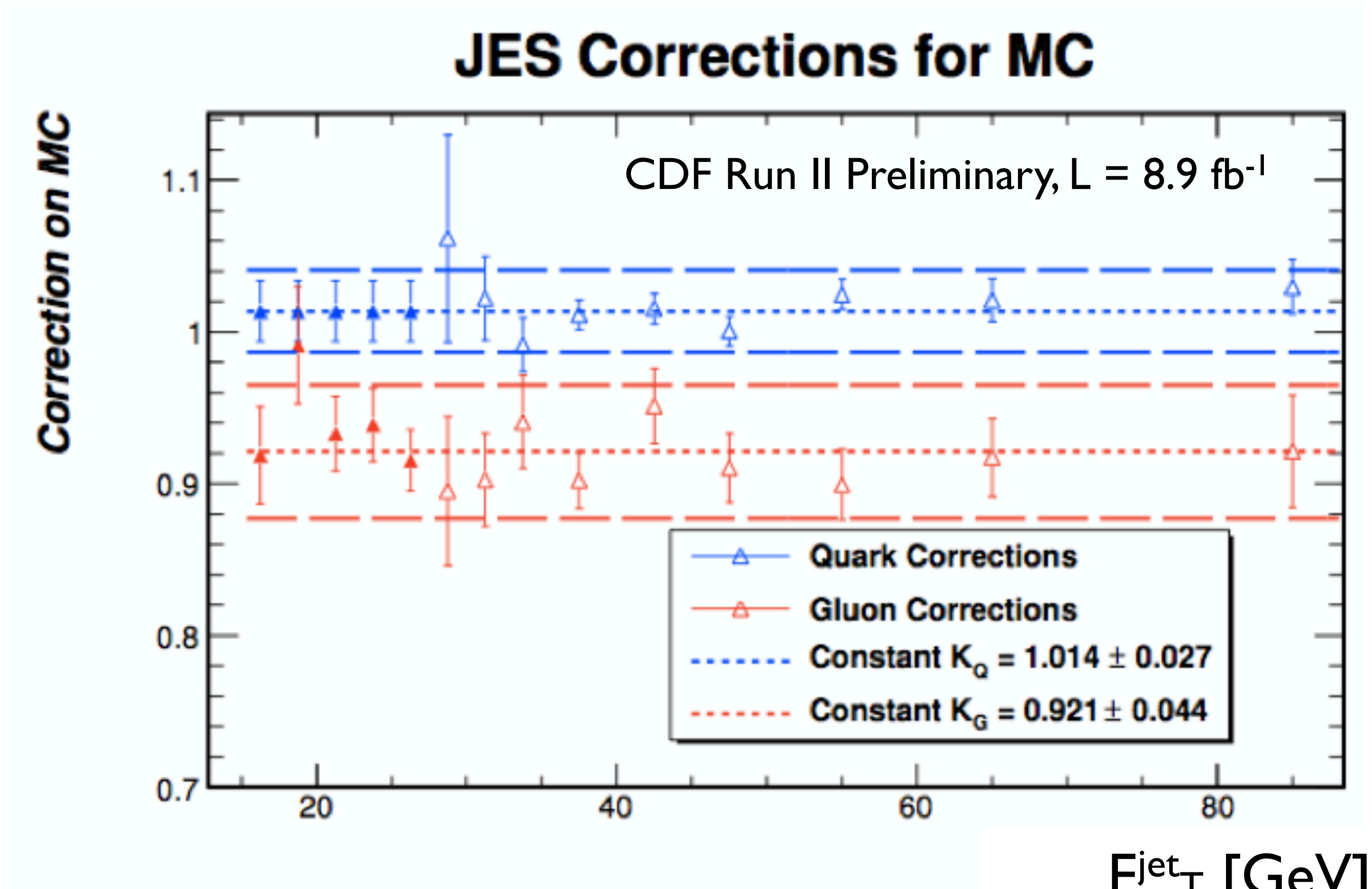
, (cross-checked with data)

= quark-JES, gluon-JES

NEW

Object identifications - jets

Extraction of quark/gluon JES



E^{jet}_T [GeV]

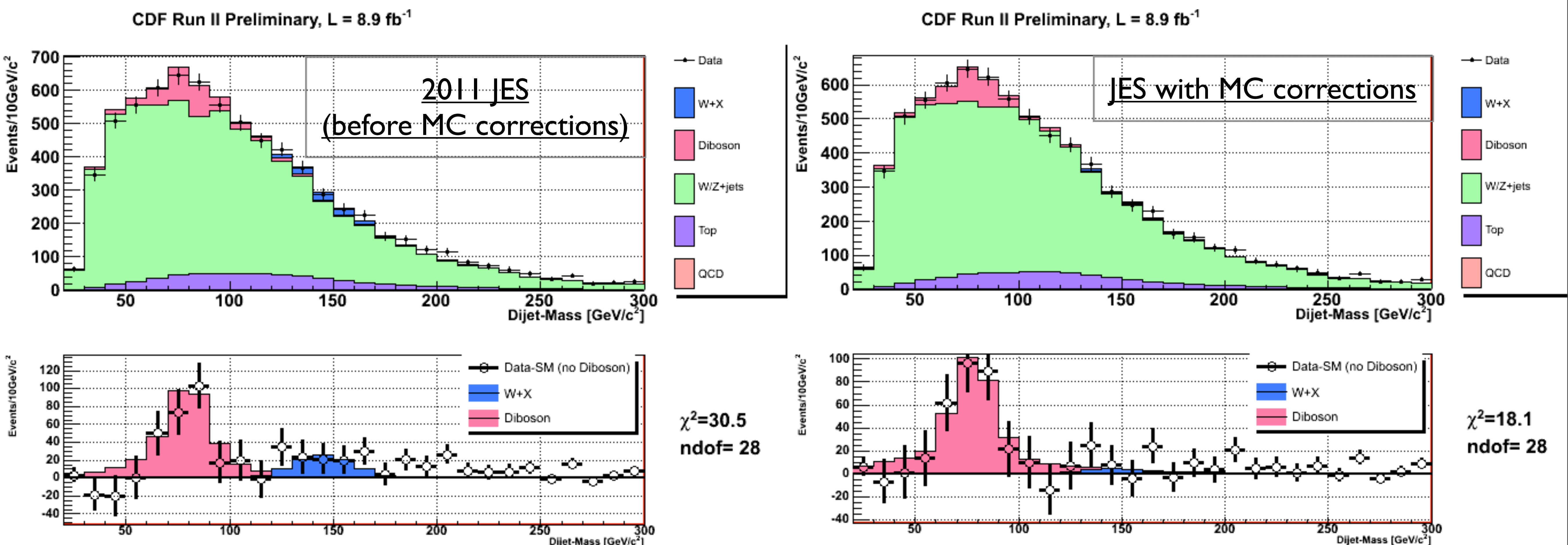
With respect to 2011 JES

- MC:
  - **quark-jets: (+1.4 +/- 2.7)%**
  - **gluon-jets: (-7.9 +/- 4.4)%**

(No corrections applied to data)

Effect of the MC corrections (Muon sample)

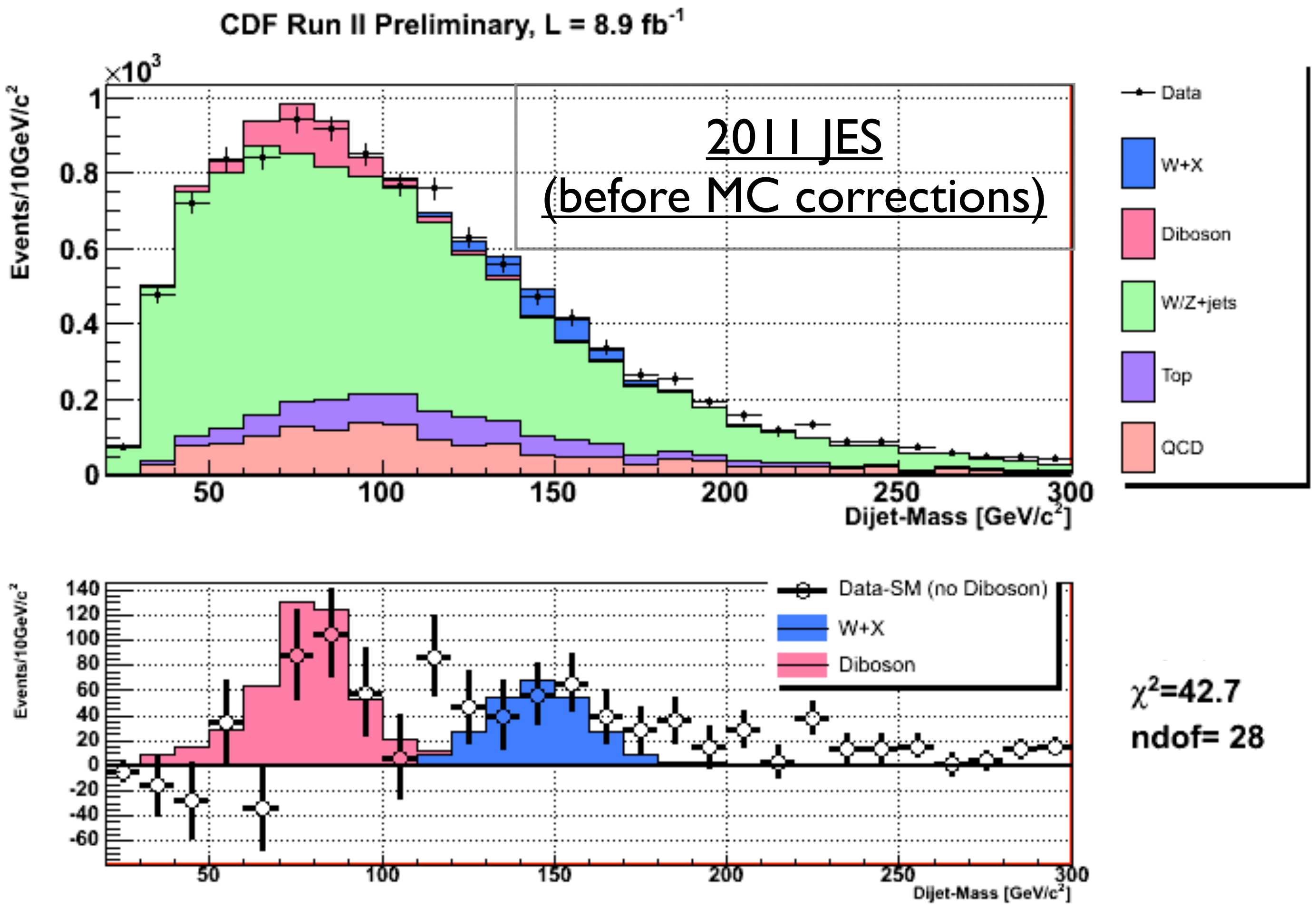
- Dijet mass in the muon sample with
  - standard JES MC (as in 2011)
  - JES MC corrections

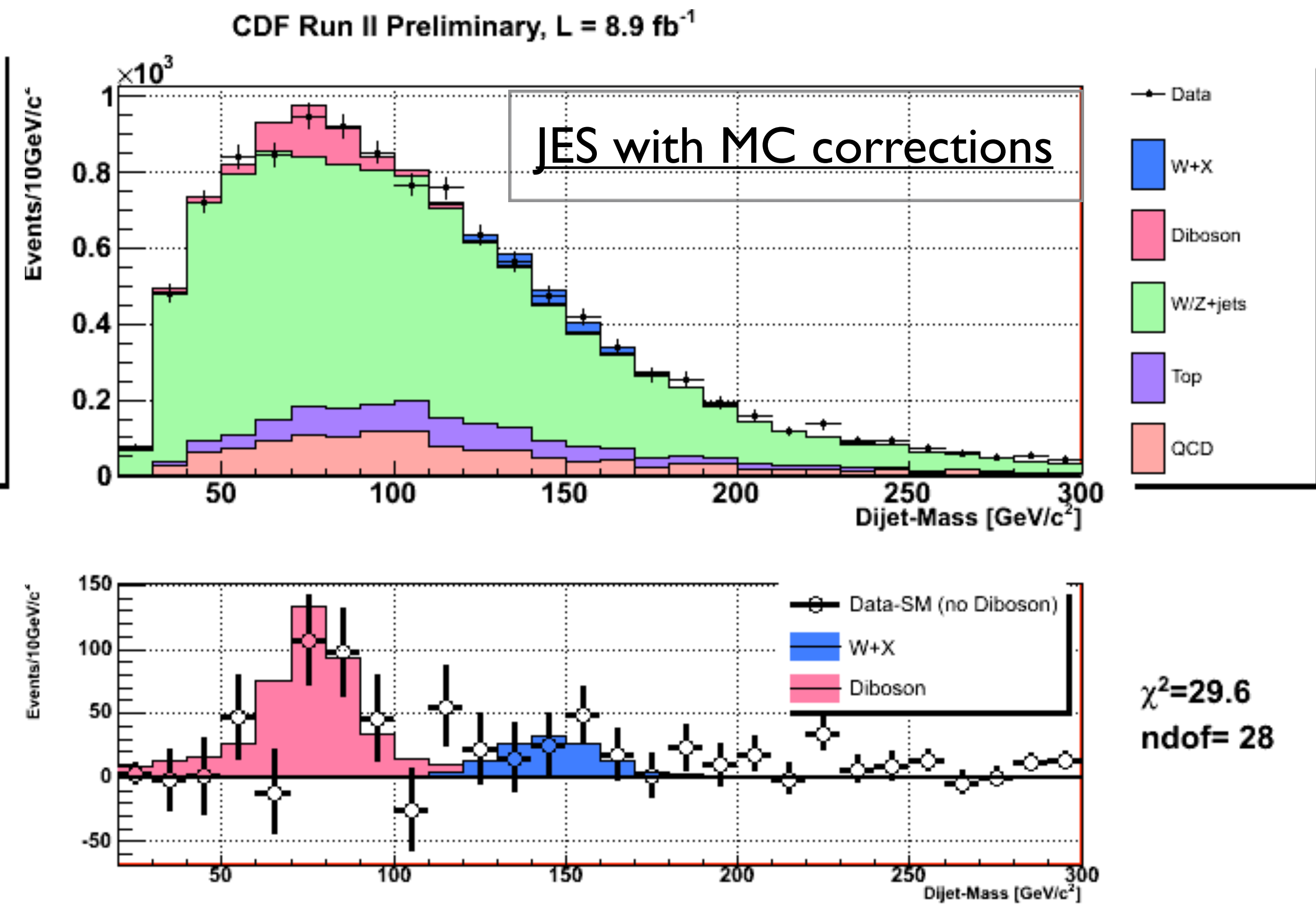


After JES MC corrections

muon sample is well described by the SM

Effect of the MC corrections (Electron sample)





- JES MC corrections improve the description of the data
- However, the same **behavior** is not seen in the **muon** and electron **samples**

Question: what can be different between the muon and electron samples?

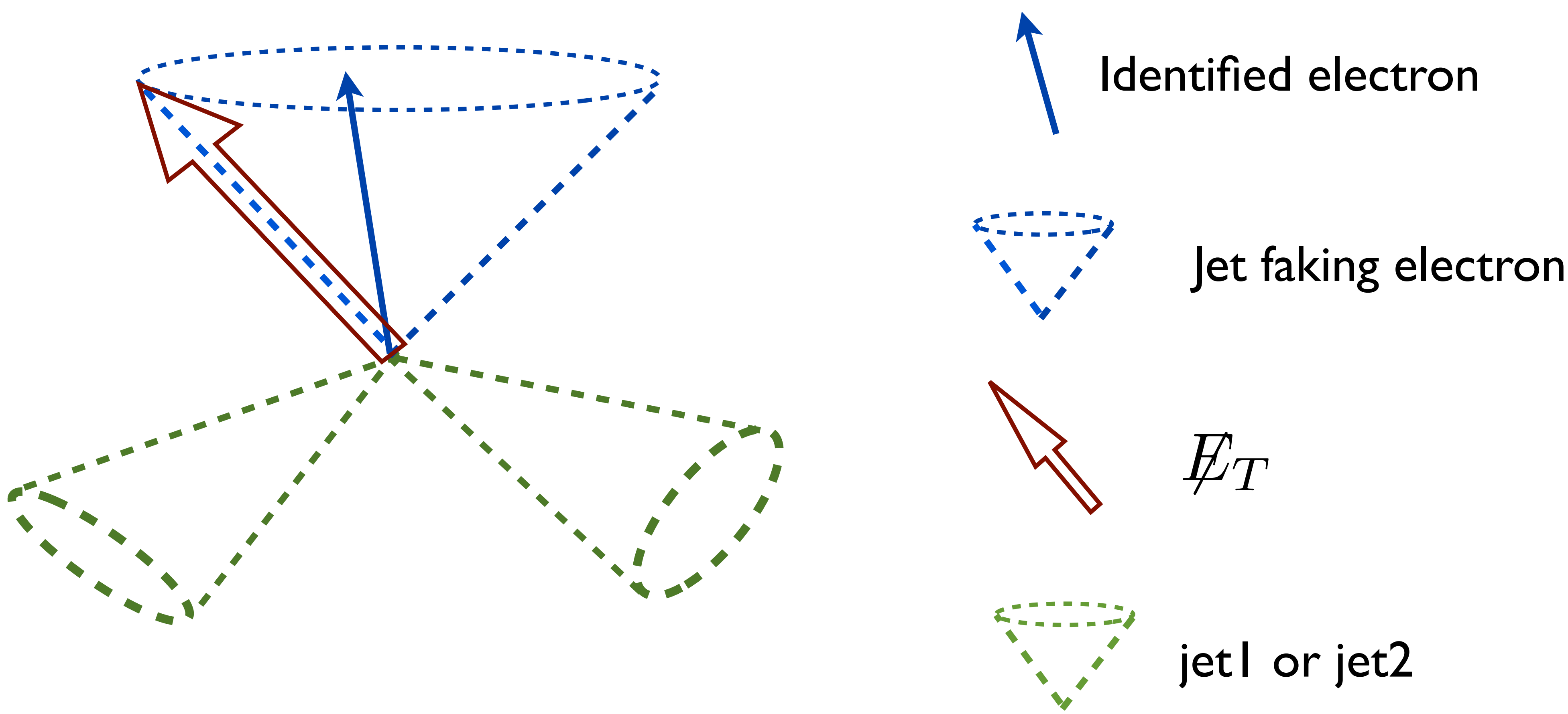
(Most obvious) answer: fake-leptons background

- *Muons: neglibible*
- *Electrons: sizeable*

- Modeling of the jet response
- Modeling of the fake-leptons

QCD multi-jets background

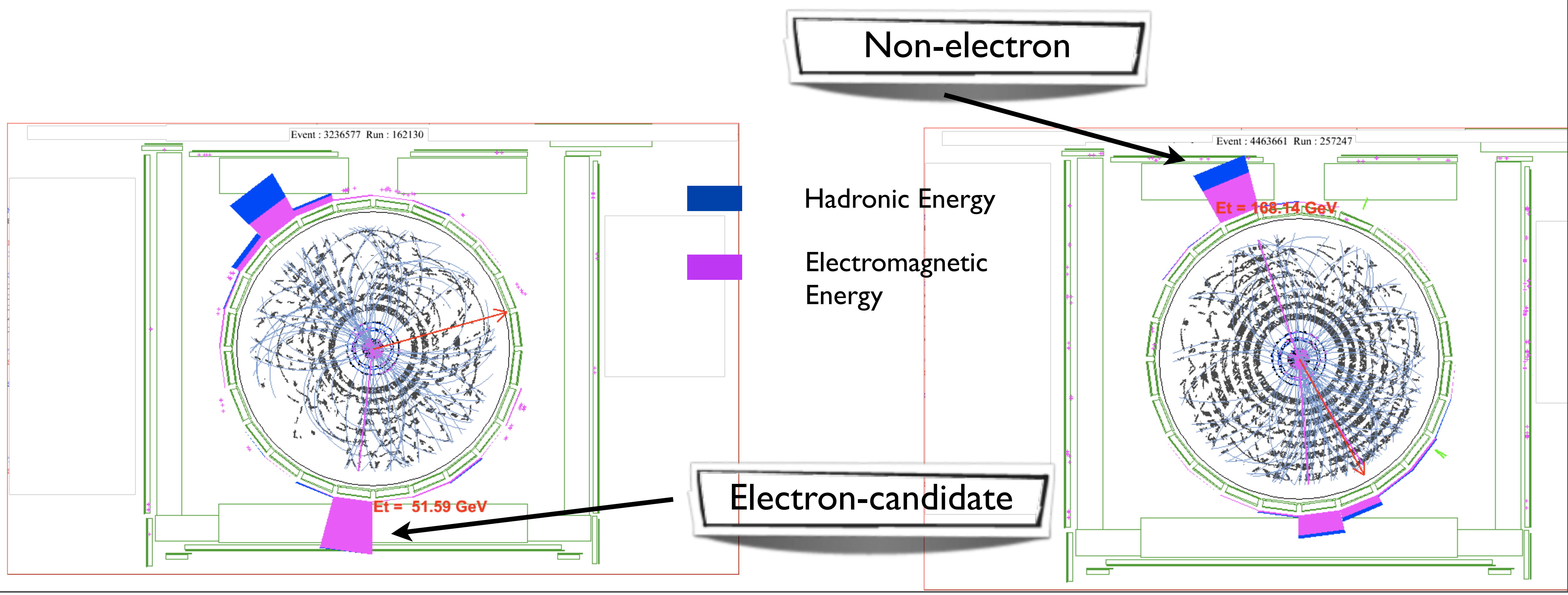
- Multi-jet selected events are typically 3 jets events
  - One jet faking the identified electron
  - $\not\!\!E_T$ generated by mis-measured calorimetric objects



QCD multi-jets background

How do we model it?

- **Using "non-electron" events**
  - Same kinematics as in electron-candidate events but two electron identification requirements are failed

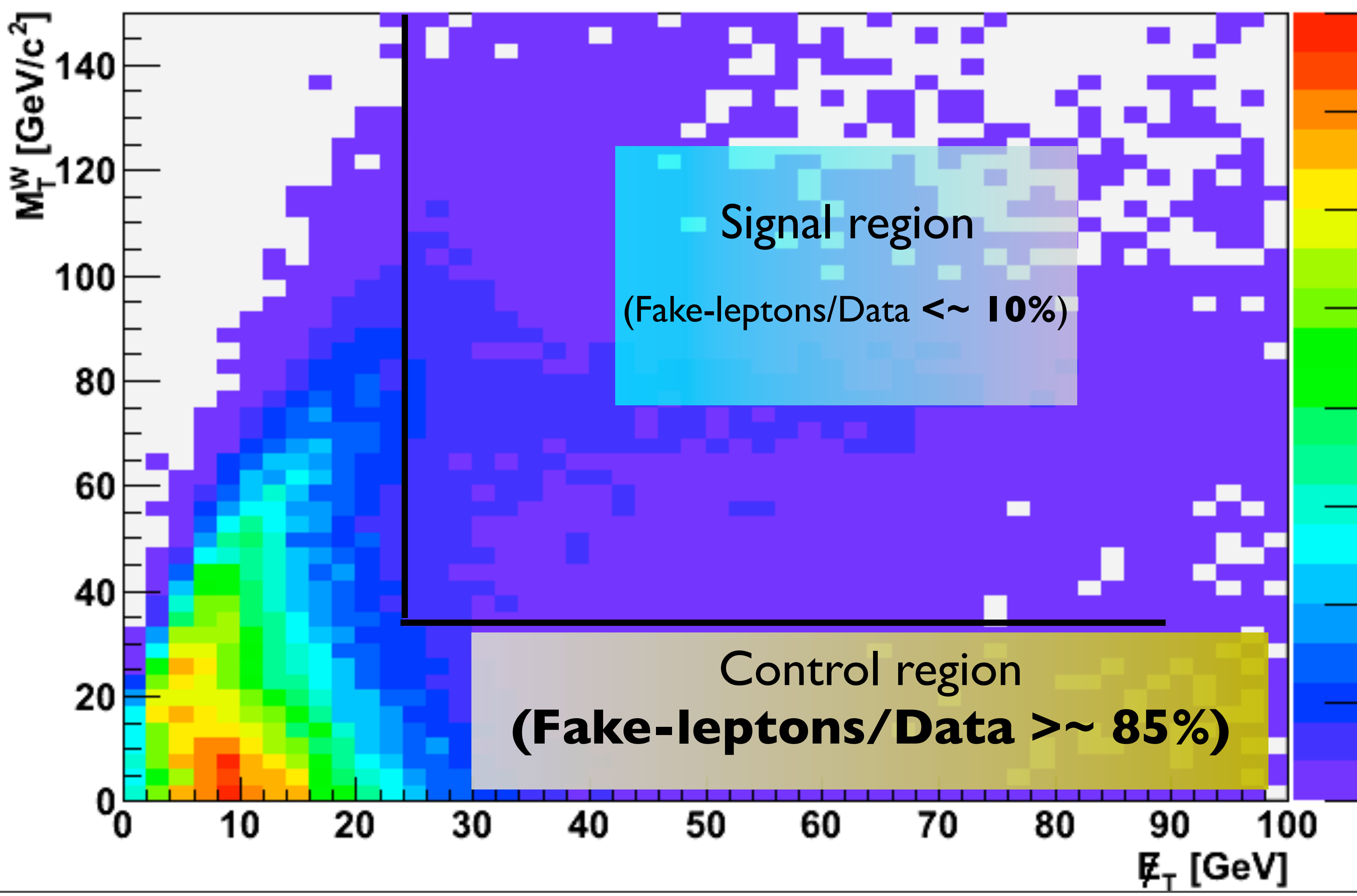


QCD multi-jets background

- How do we judge whether the non-electron model is appropriate or not?

Control region

- *Defined to enhance the fake-leptons contamination in the sample*
- Need to magnify the symptoms to spot the problems!



QCD multi-jets background

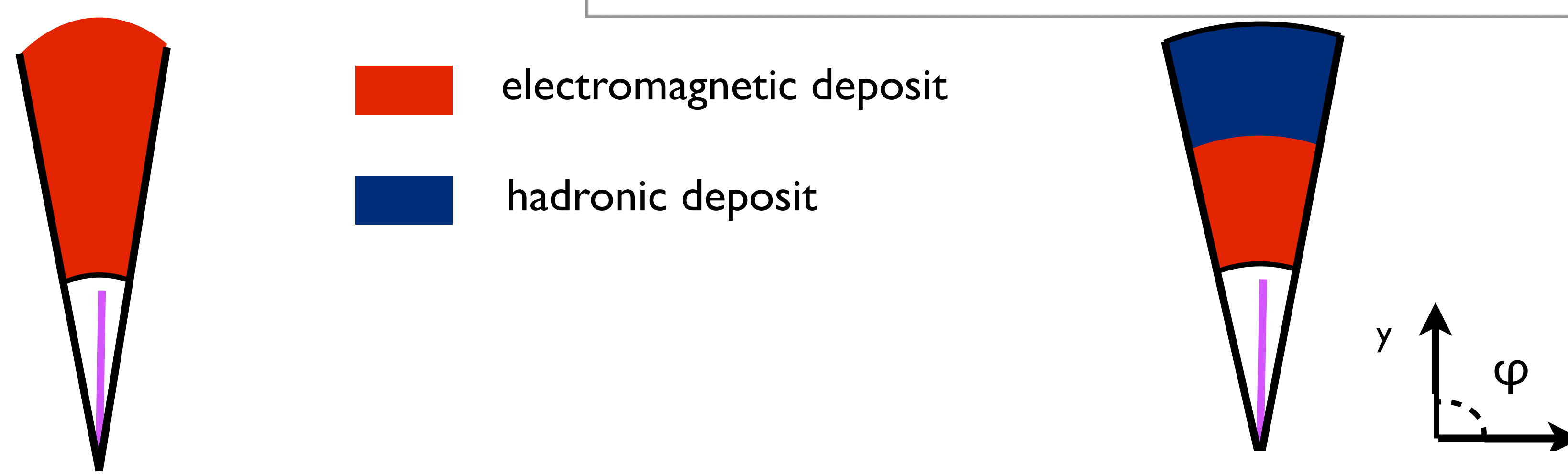
- *Quick reminder:* *main* difference between electron candidates and non-electrons

---

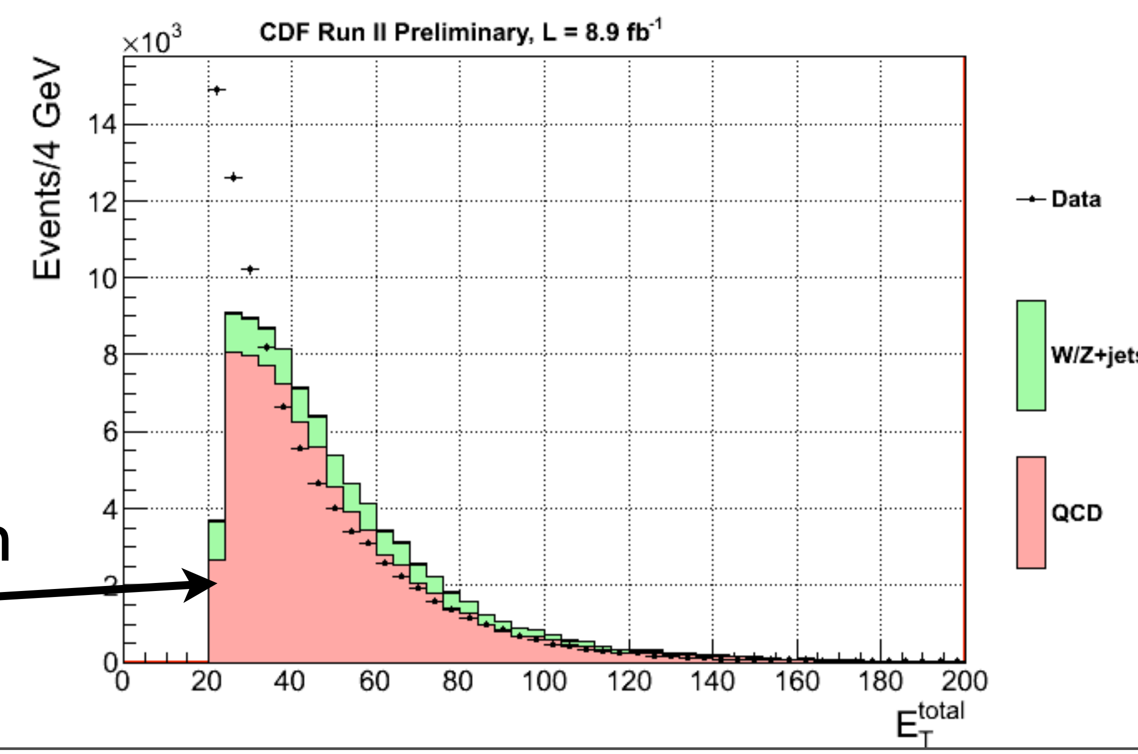
Electron candidate

Non-electron
(failing of two identification requirements)

Electromagnetic fraction

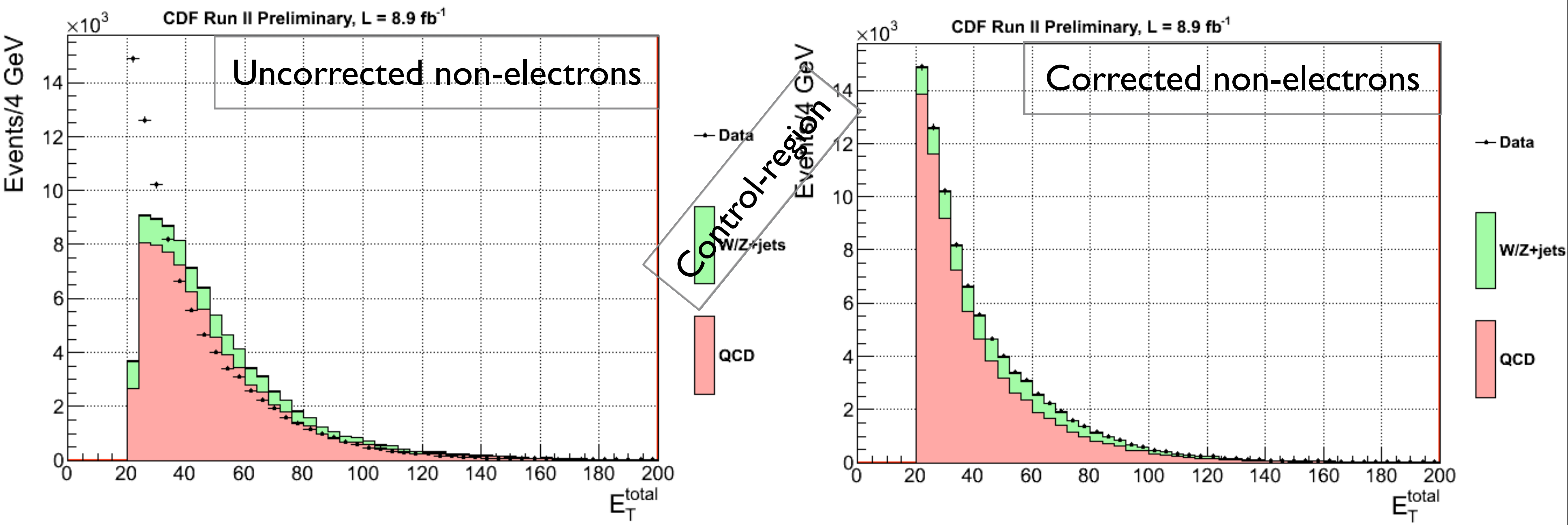


- Electron-trigger cuts on $E_T^{electromagnetic}$ rather than E_T^{total}
    - close to threshold, trigger efficiency is much lower for non-electrons



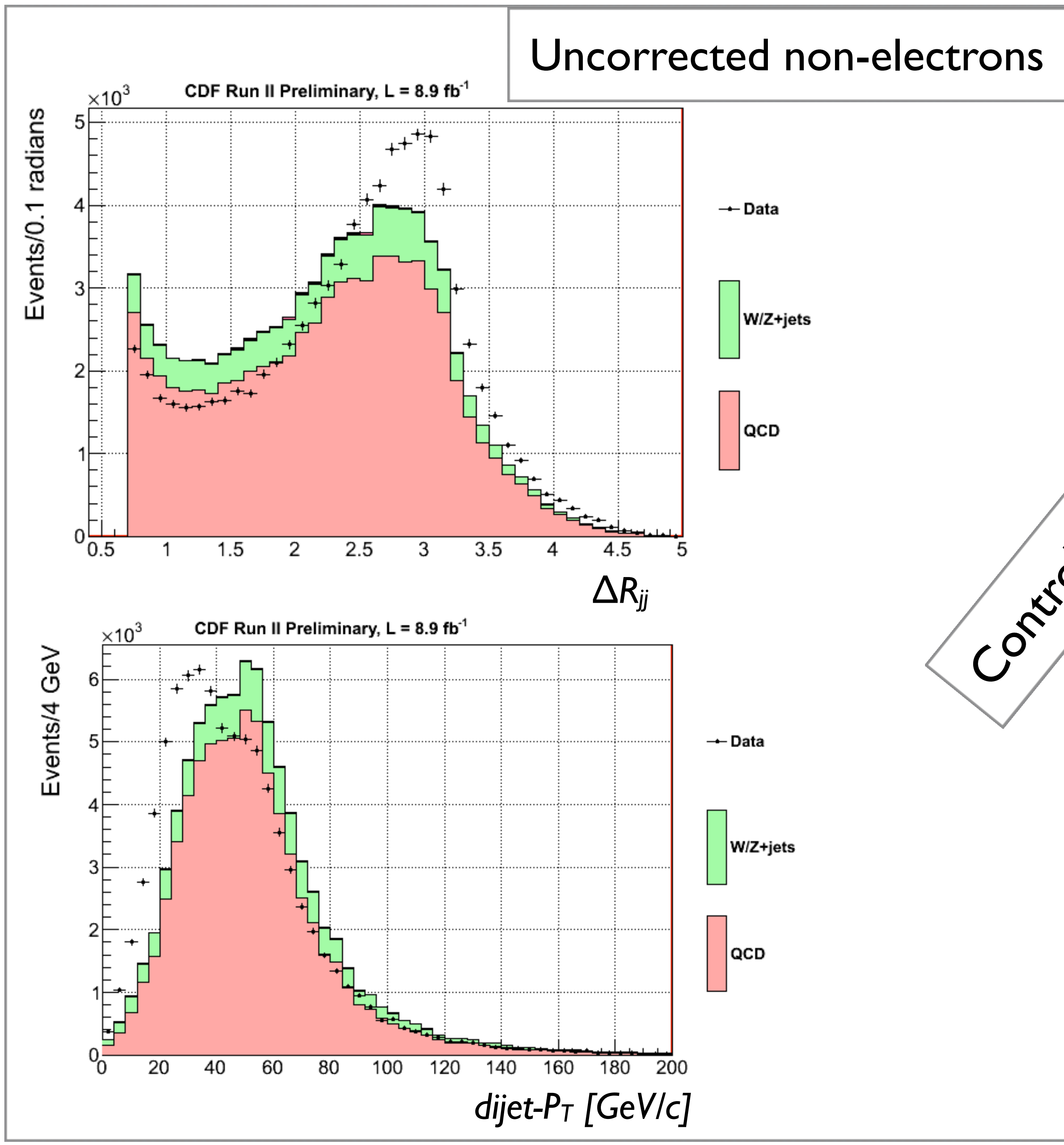
QCD multi-jets background

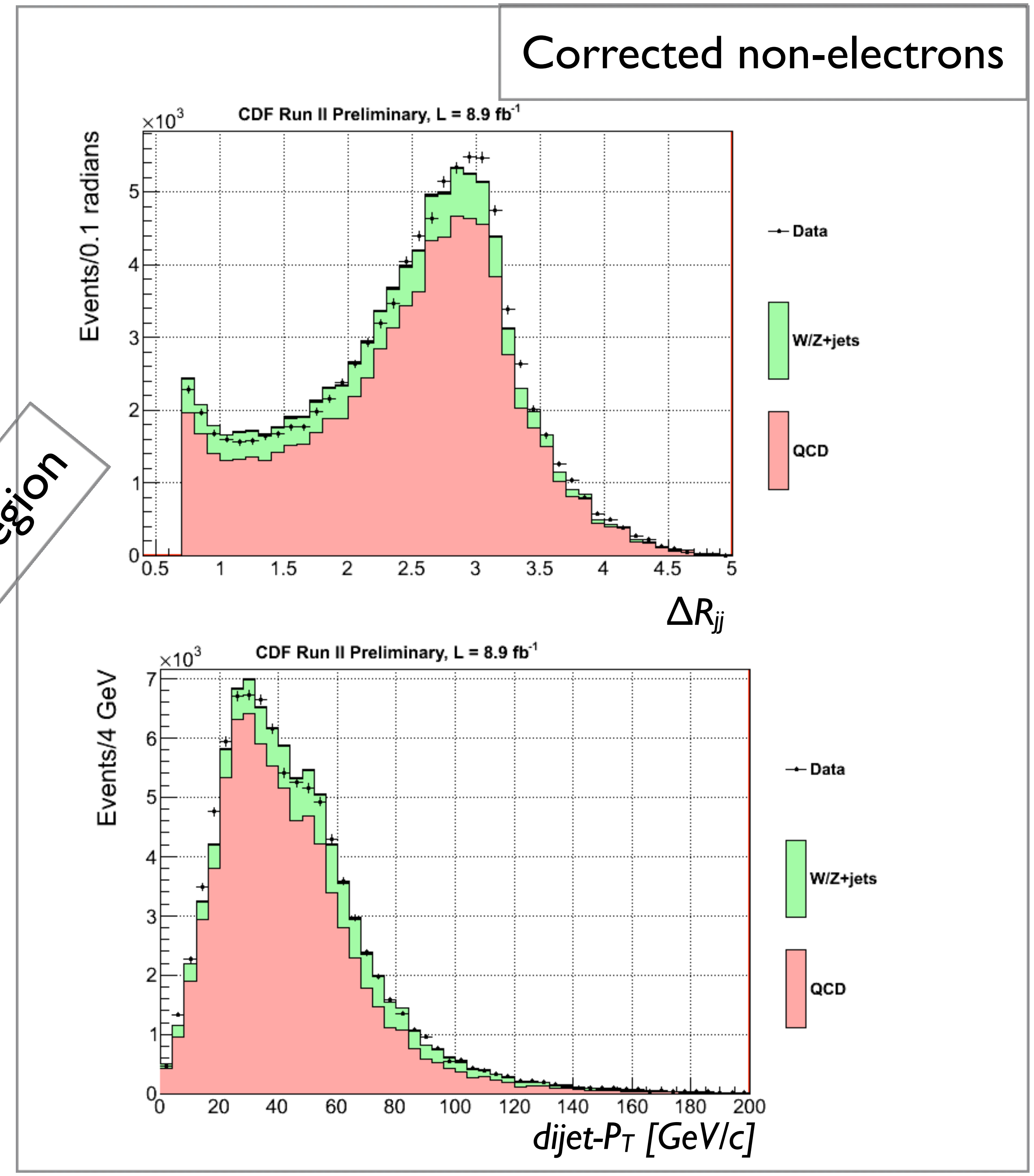
- To remove the trigger bias we determine a re-weighting in the control region and apply it in the signal region



QCD multi-jets background

- We compare shapes before and after the correction

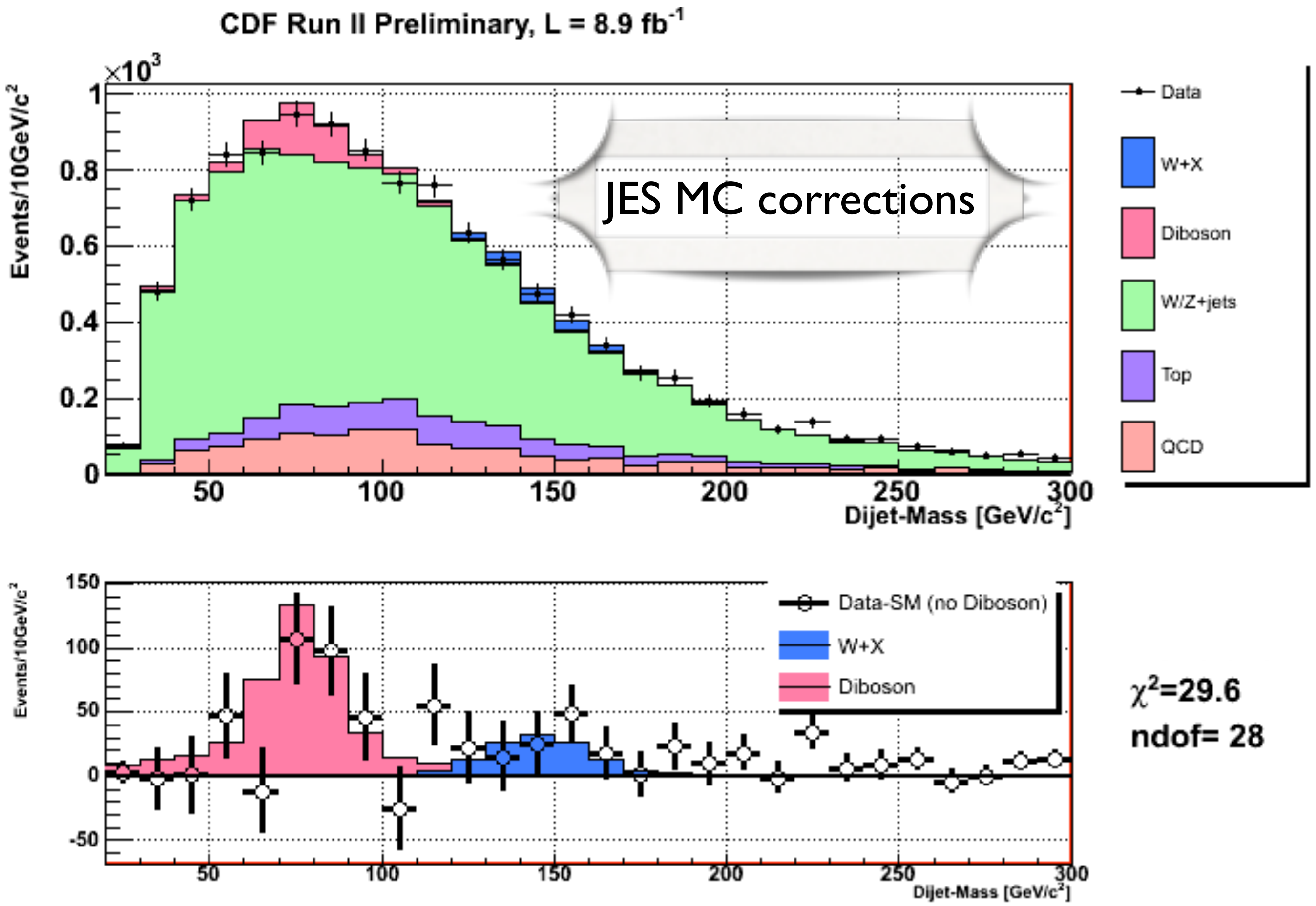


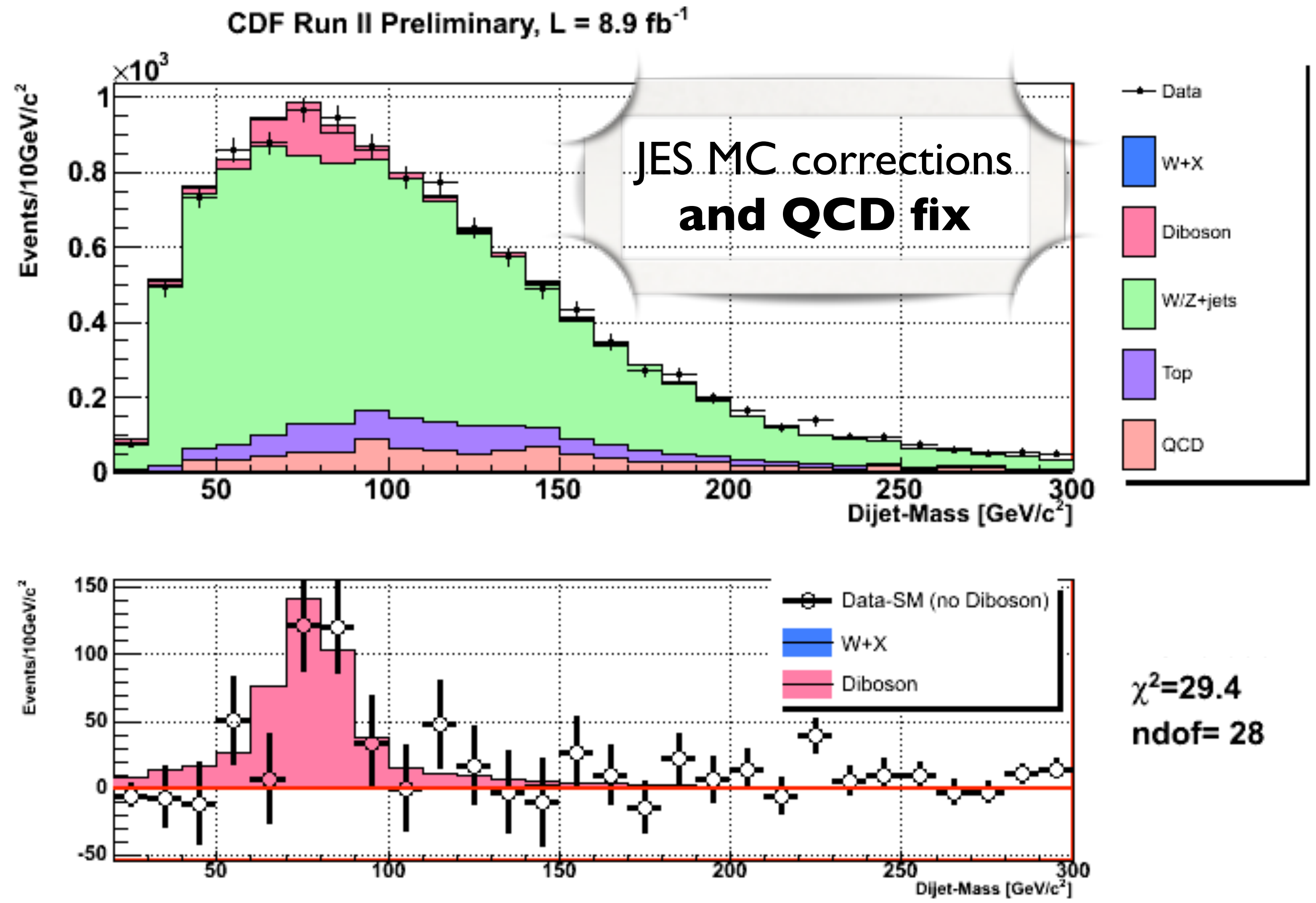


Control-region

QCD multi-jets background
(Electron sample)

7/7





After JES MC corrections and QCD fix

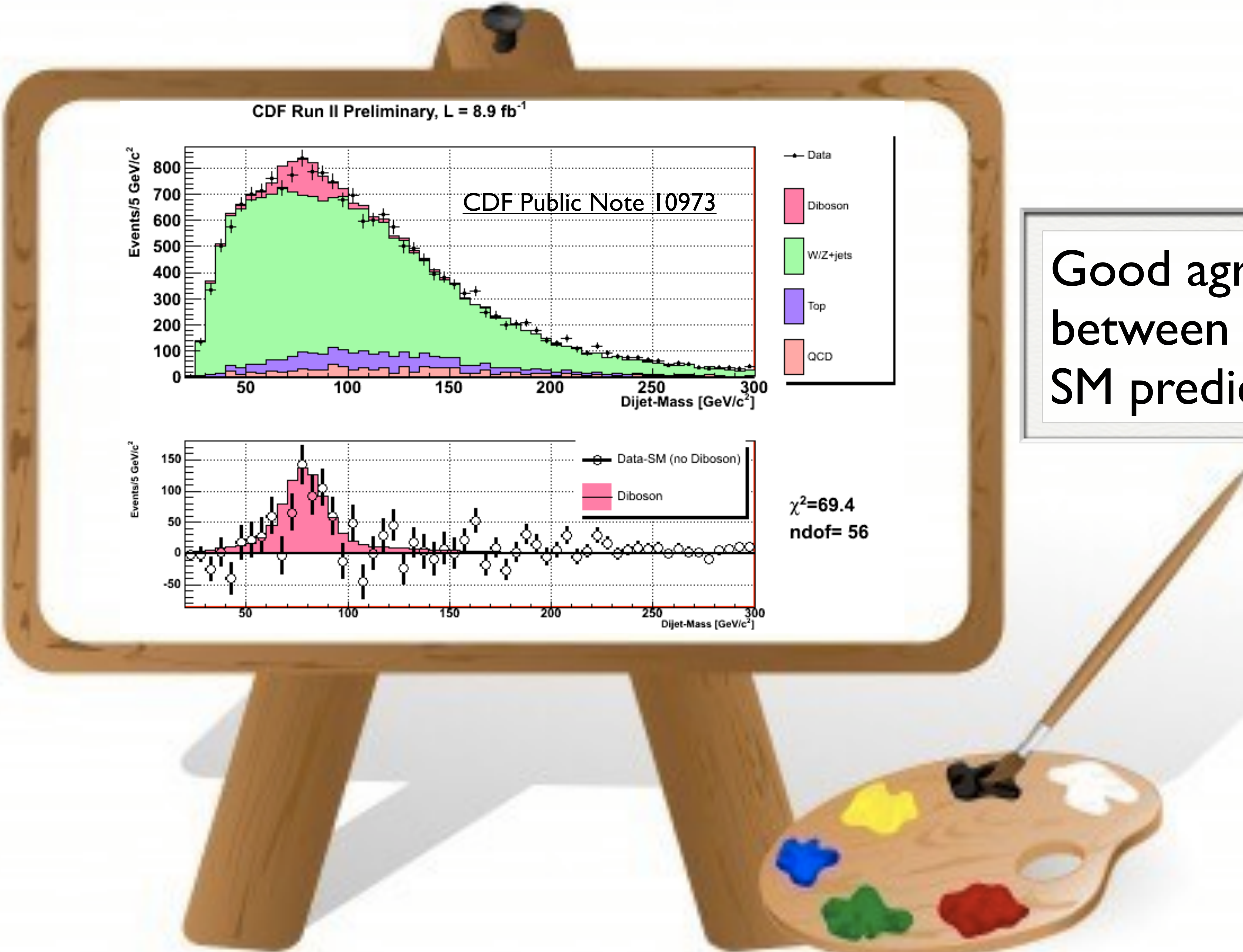
full consistency

between the **electron and the muon** samples

Final fit: procedure

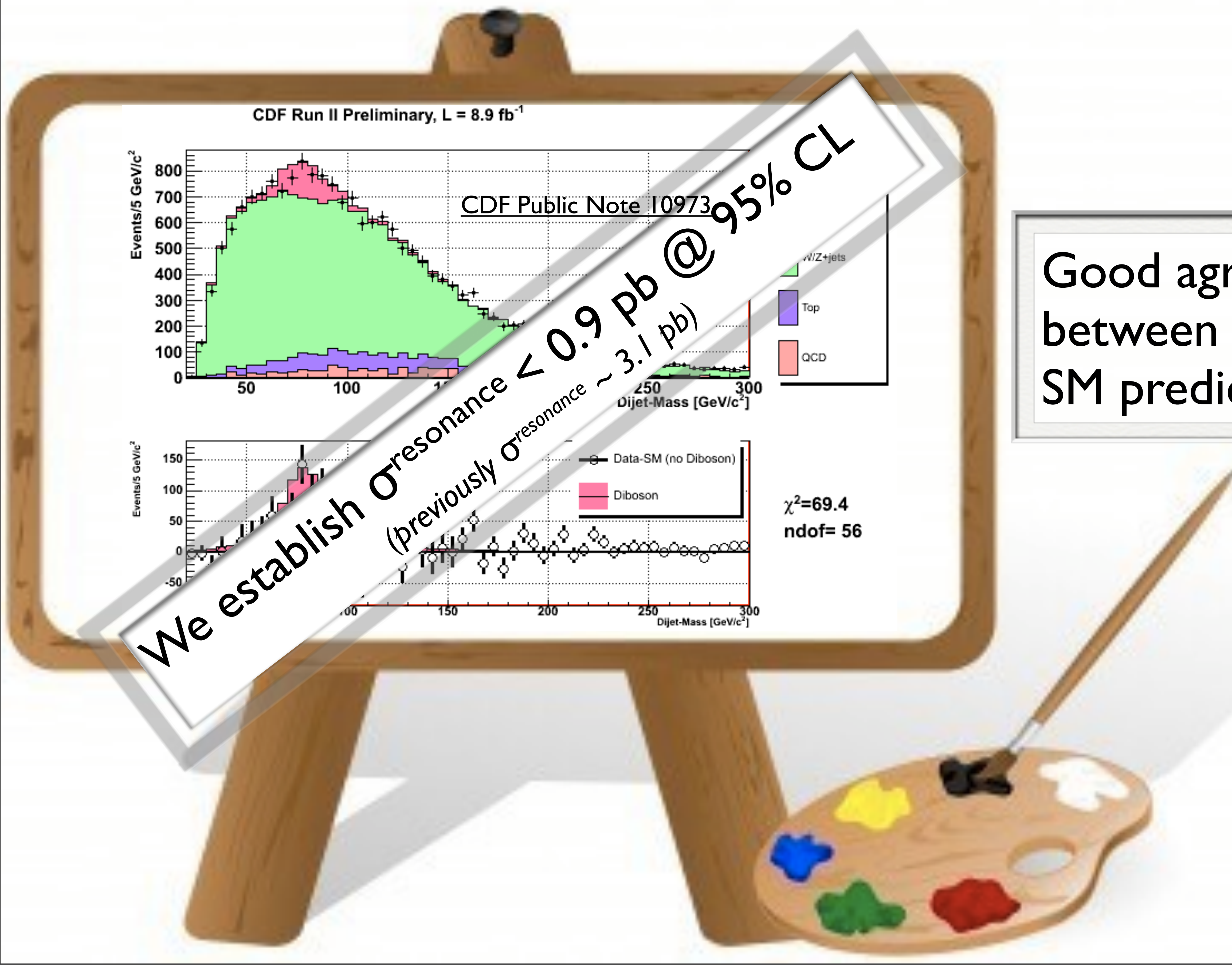
- Fit dijet mass using 4 templates:
  - W/Z+jets
  - Top
  - Diboson
  - QCD multi-jets background
- Maximization of binned likelihood function
- Nuisance parameters in the fit
  - Jet energy scale
  - Background shapes and normalization

Results: electrons + muons



Good agreement between data and SM predictions

Results: electrons + muons



Good agreement between data and SM predictions

Conclusions

- Big effort made by CDF to reach this point
- Concerned by disagreement between data and SM expectations in the W+2jets sample: deficiencies in models or new physics?
- We investigated many, and we found two subtle potential issues
  - **Important differences in the modeling of quark and gluon jet response**
  - **Inaccurate modeling of a major background (fake electrons from QCD multijets)**
- We applied the appropriate corrections and we found that the data are well described by the SM.

It took us ~2 years to complete this task

Conclusions

- Big effort made by CDF to reach this point
- Concerned by disagreement between data and SM expectations in the W+2jets sample: deficiencies in models or new physics?
- We investigated many, and we found two subtle potential issues

Thanks for the attention!

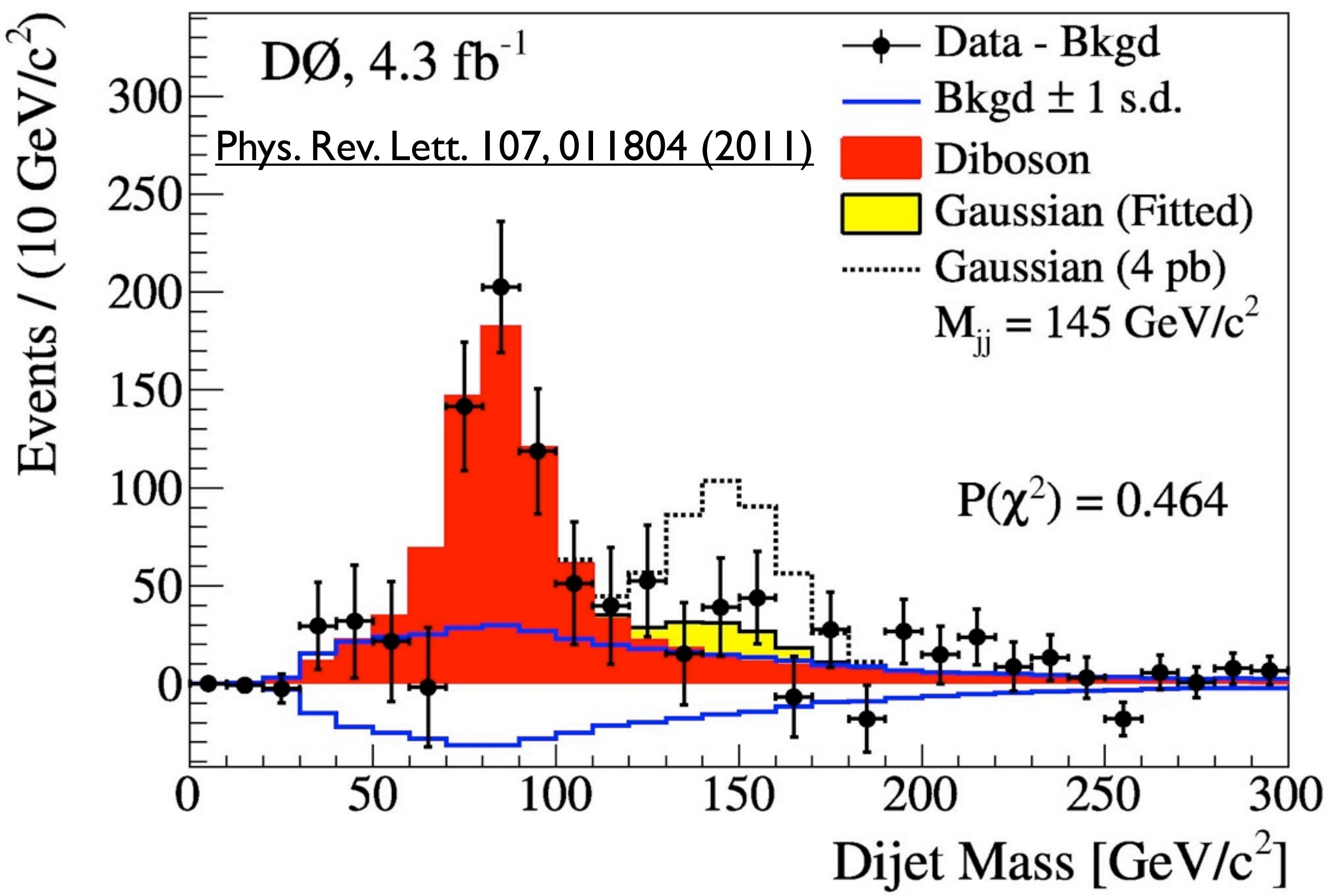
P.S: more details about these studies will be published soon in a PRD

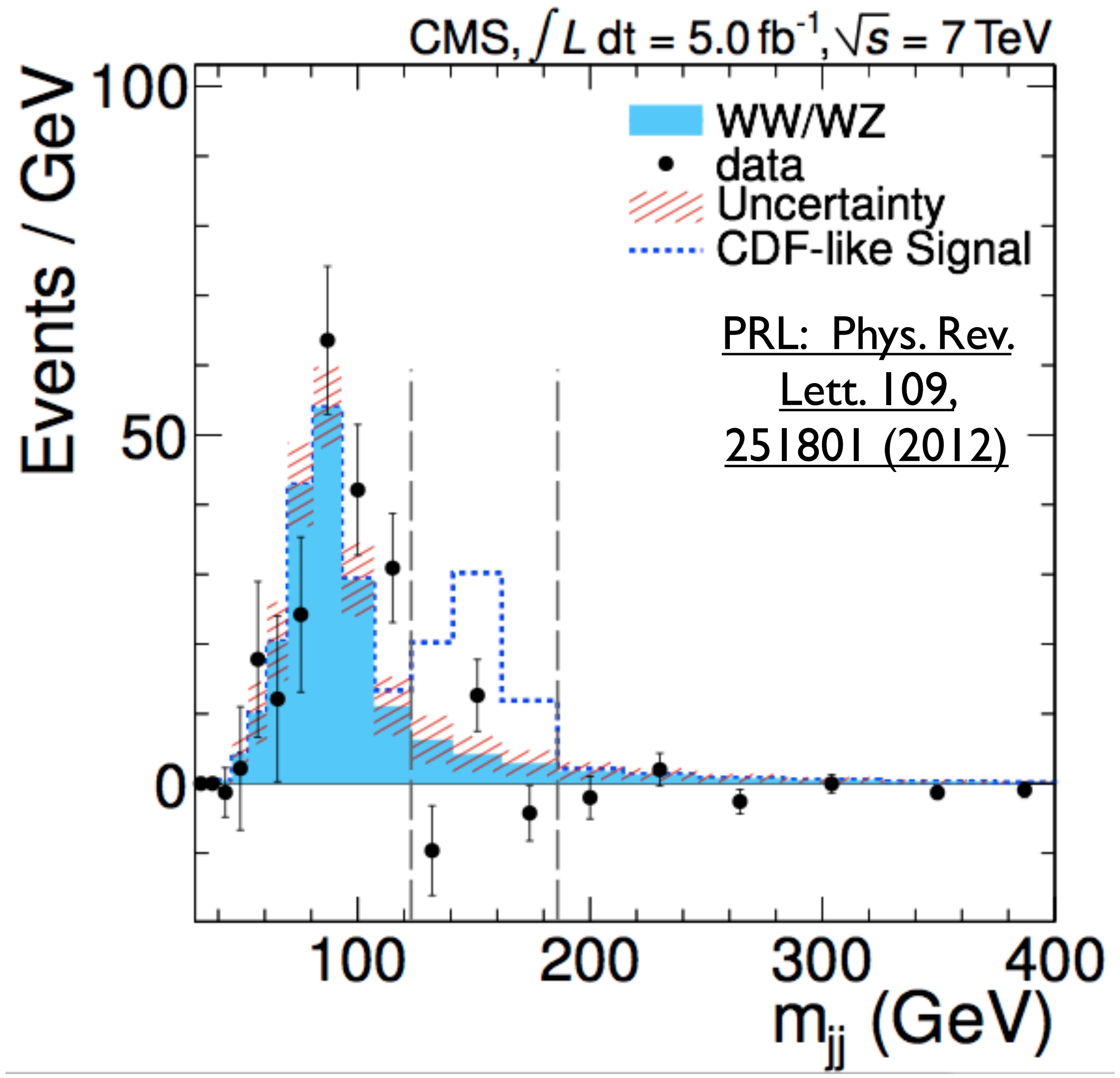
It took us ~2 years to complete this task

- backup

State of the art from other experiments

- Both D0 and CMS performed similar analyses



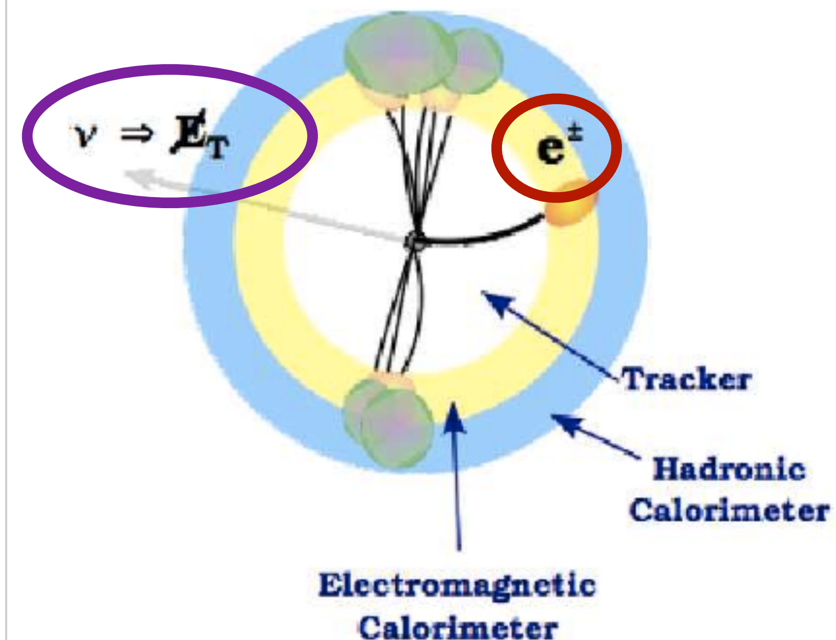


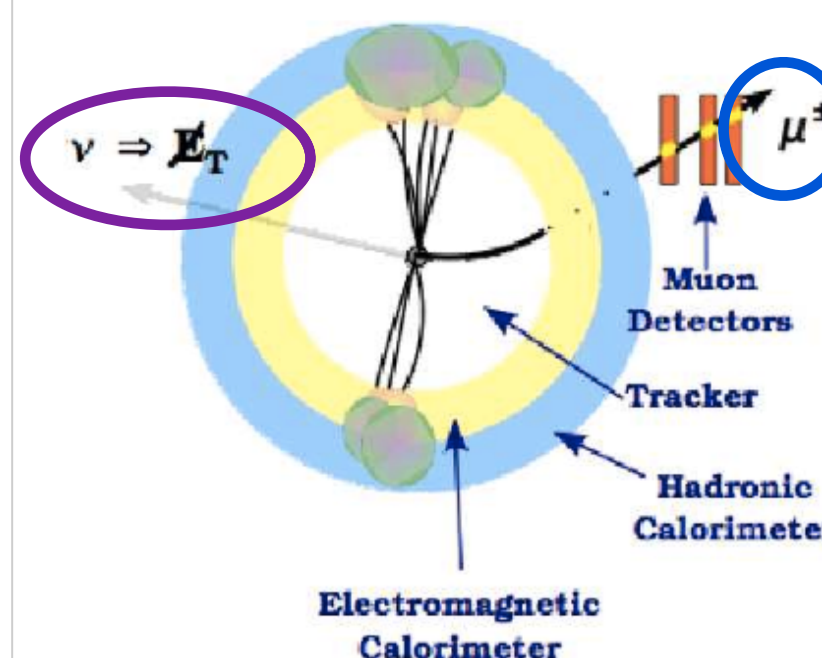
- Also, preliminary analysis from ATLAS (ATLAS-CONF-2011-097)

Similar effects are not observed

Object identifications - leptons, ν

- Want to efficiently collect Ws:
  - Trigger on charged lepton
  - Offline lepton identification:
    - Electrons:
      - Track matched to an isolated calorimetric deposit of one or two towers
        - Mostly electromagnetic (>90%)
    - Muons:
      - Isolated track matched to a small calorimetric deposit and hits in the muon chambers.
    - Neutrinos: large $\not\!\!E_T$
      - $\not\!\!E_T$ corrected for calorimeter inefficiencies and the presence of muons



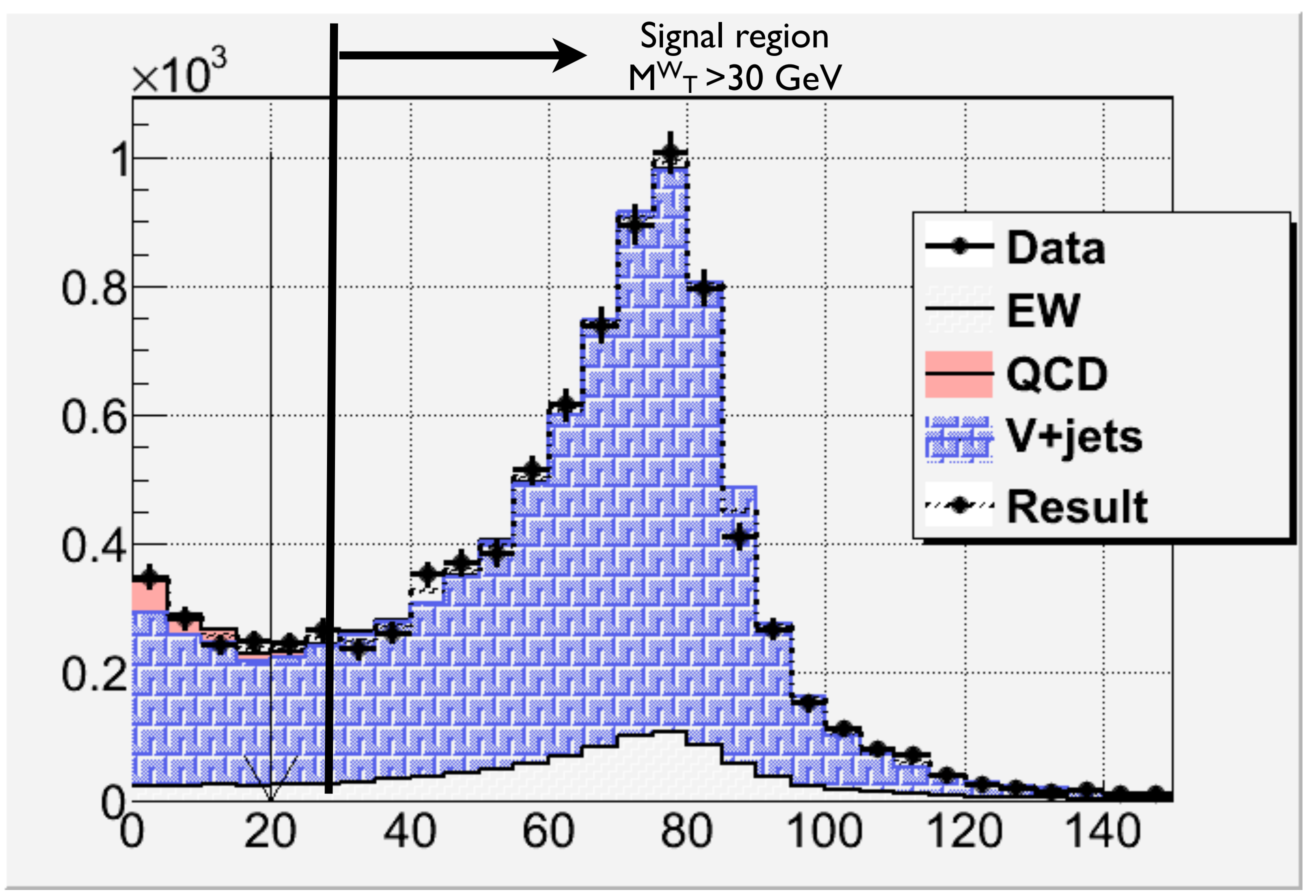


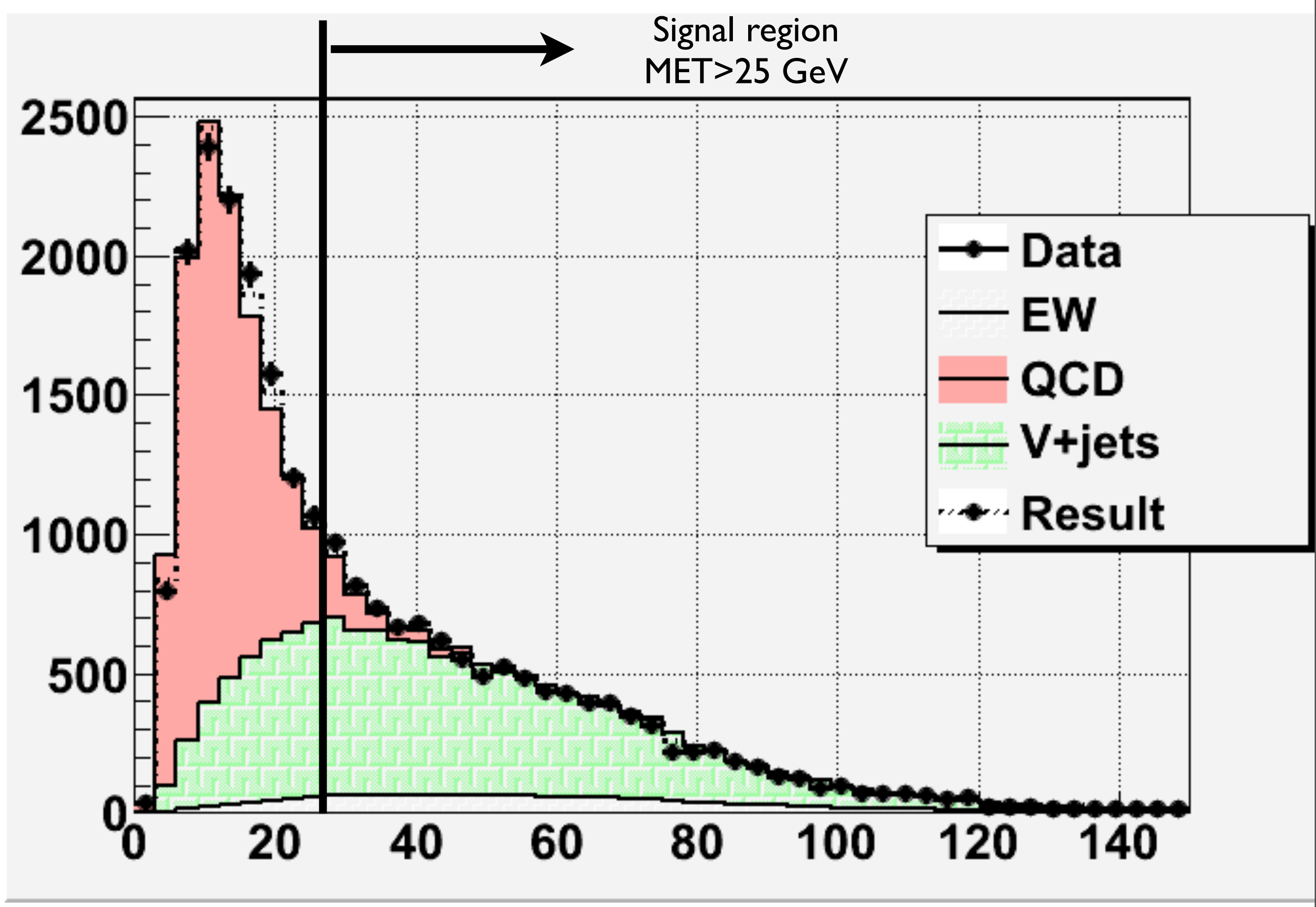
Expected yields

Process	Rate (Electrons)	Rate (Muons)
Signal	101.6 ± 1.2	76.1 ± 1.0
WW	487.7 ± 3.8	315.9 ± 2.7
tt	670 ± 2.4	430.5 ± 1.7
single-top	160.8 ± 0.6	106.3 ± 0.5
Zjets	248.2 ± 2.9	471.6 ± 2.7
Wjets	8899.6 ± 35.4	5959.3 ± 24.1
QCD	898.1 ± 65.7	20.2 ± 1.4
Total	11466.0 ± 74.8	7380.0 ± 24.5

SM prediction - QCD rate

- Determined by fitting the MET/M^W_T distributions
  - Top pair, single-top, Diboson constrained to theoretical cross-section within 6%
  - W/Z+jets, QCD multi-jets free to float

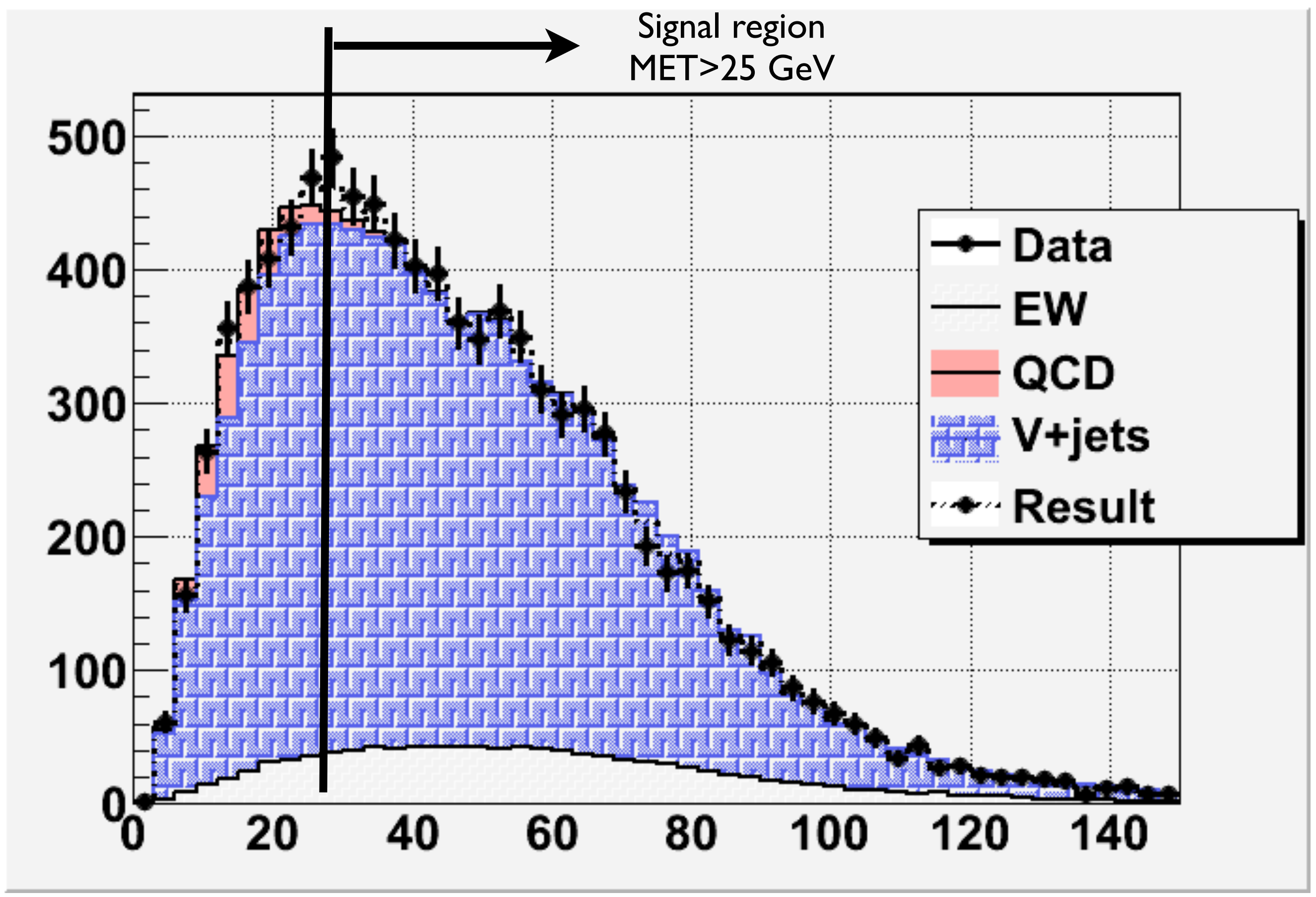


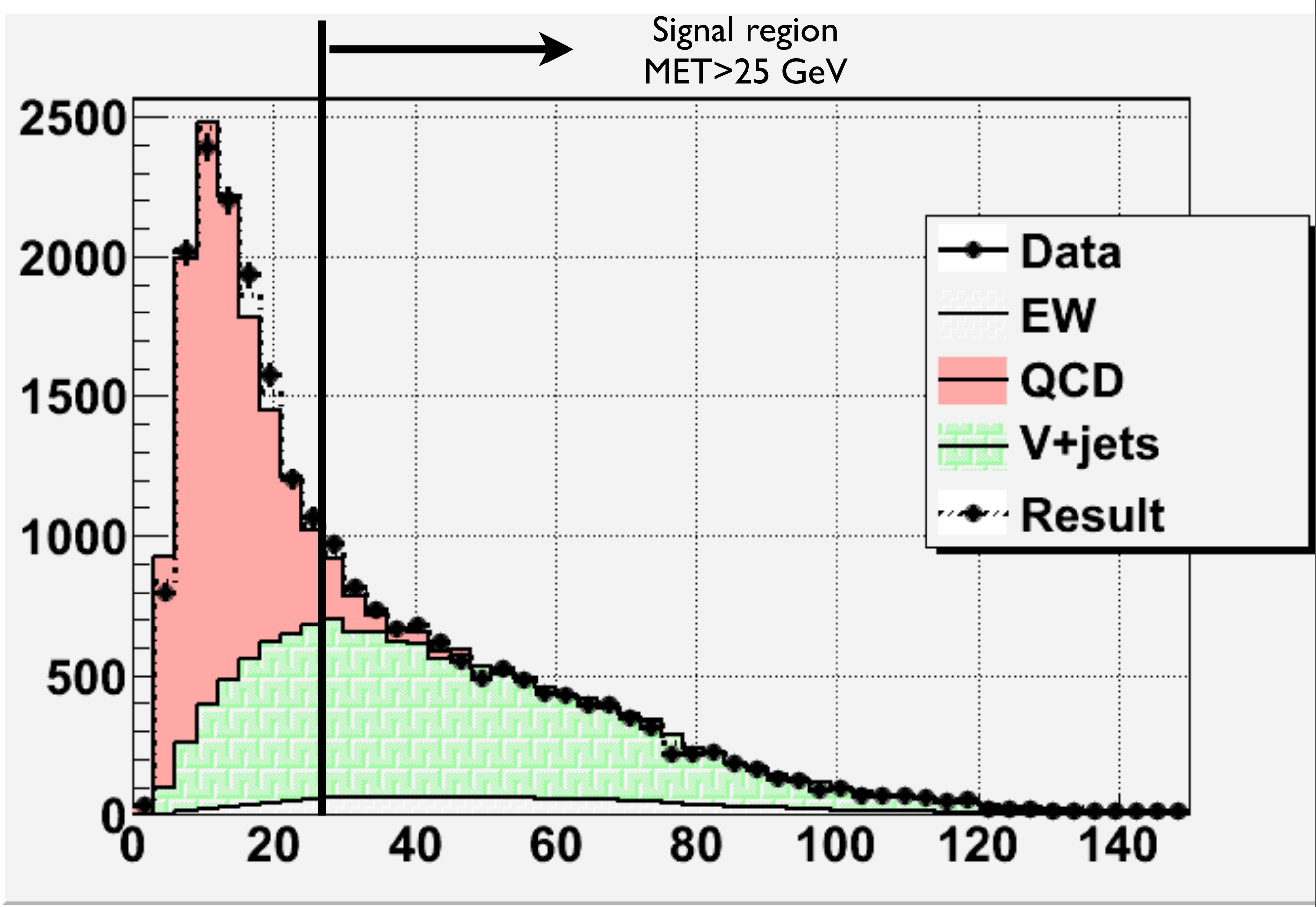


SM prediction - QCD rate

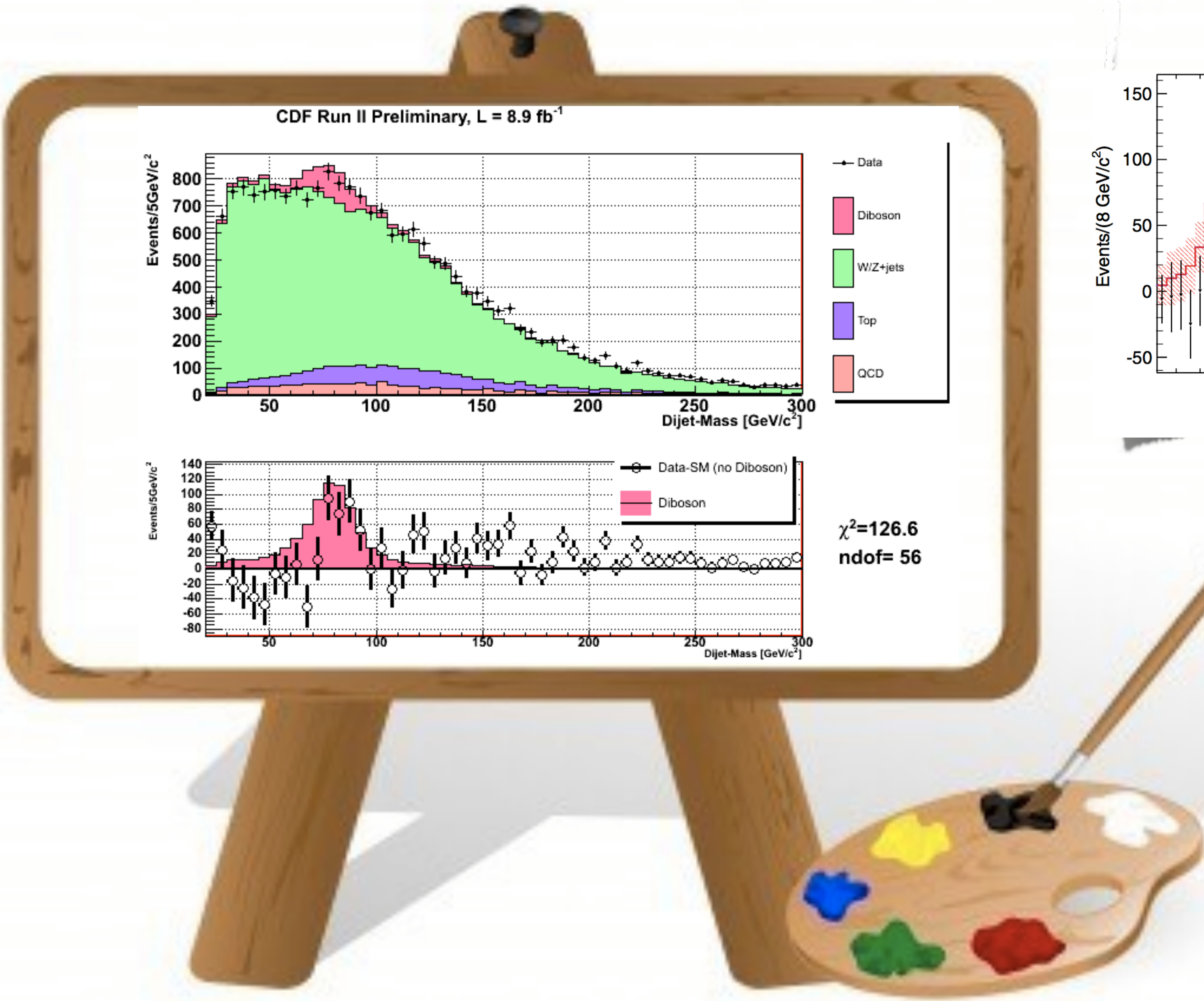
3/6

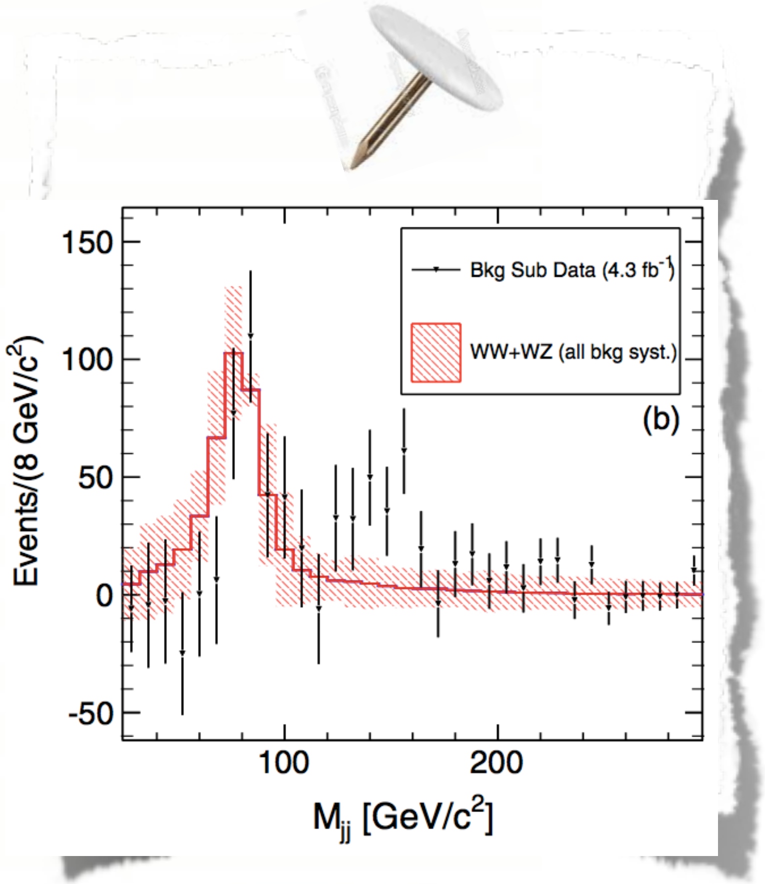
- Determined by fitting the MET distributions
  - Top pair, single-top, Diboson constrained to theoretical cross-section within 6%
  - W/Z+jets, QCD multi-jets free to float



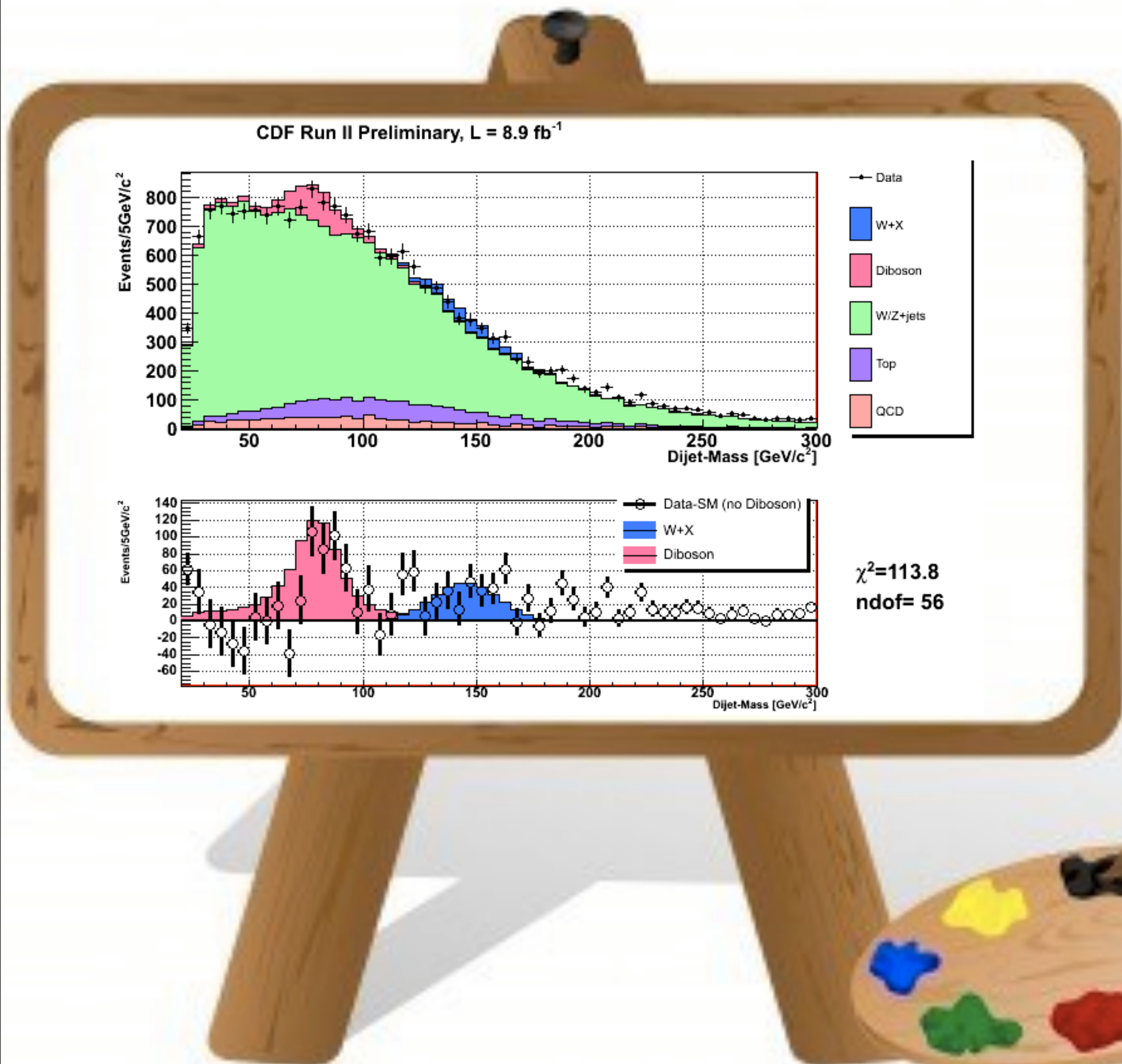


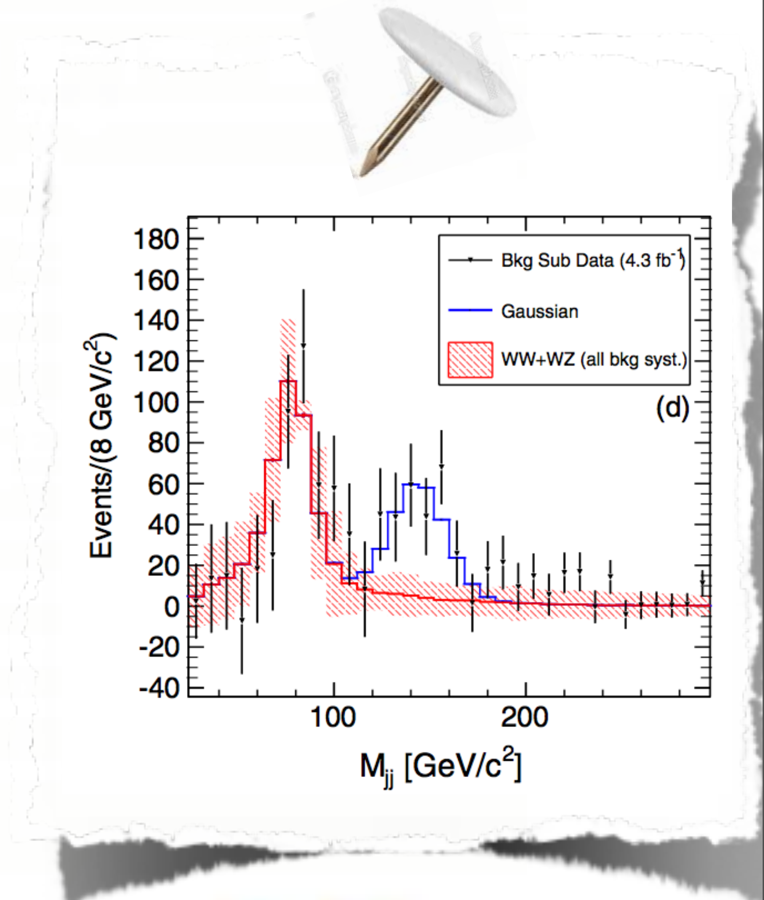
Our updated version of the excess



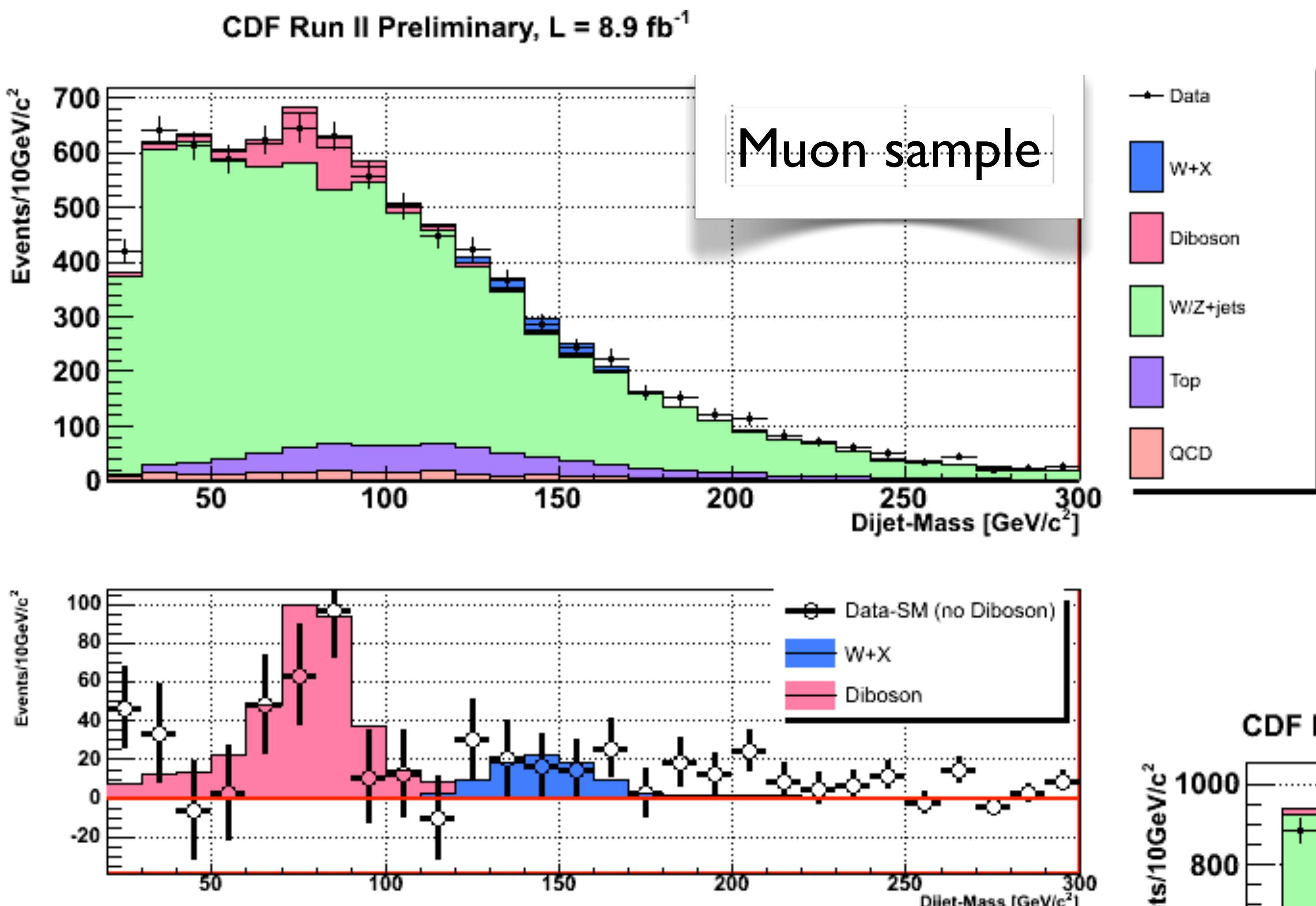


Our updated version of the excess



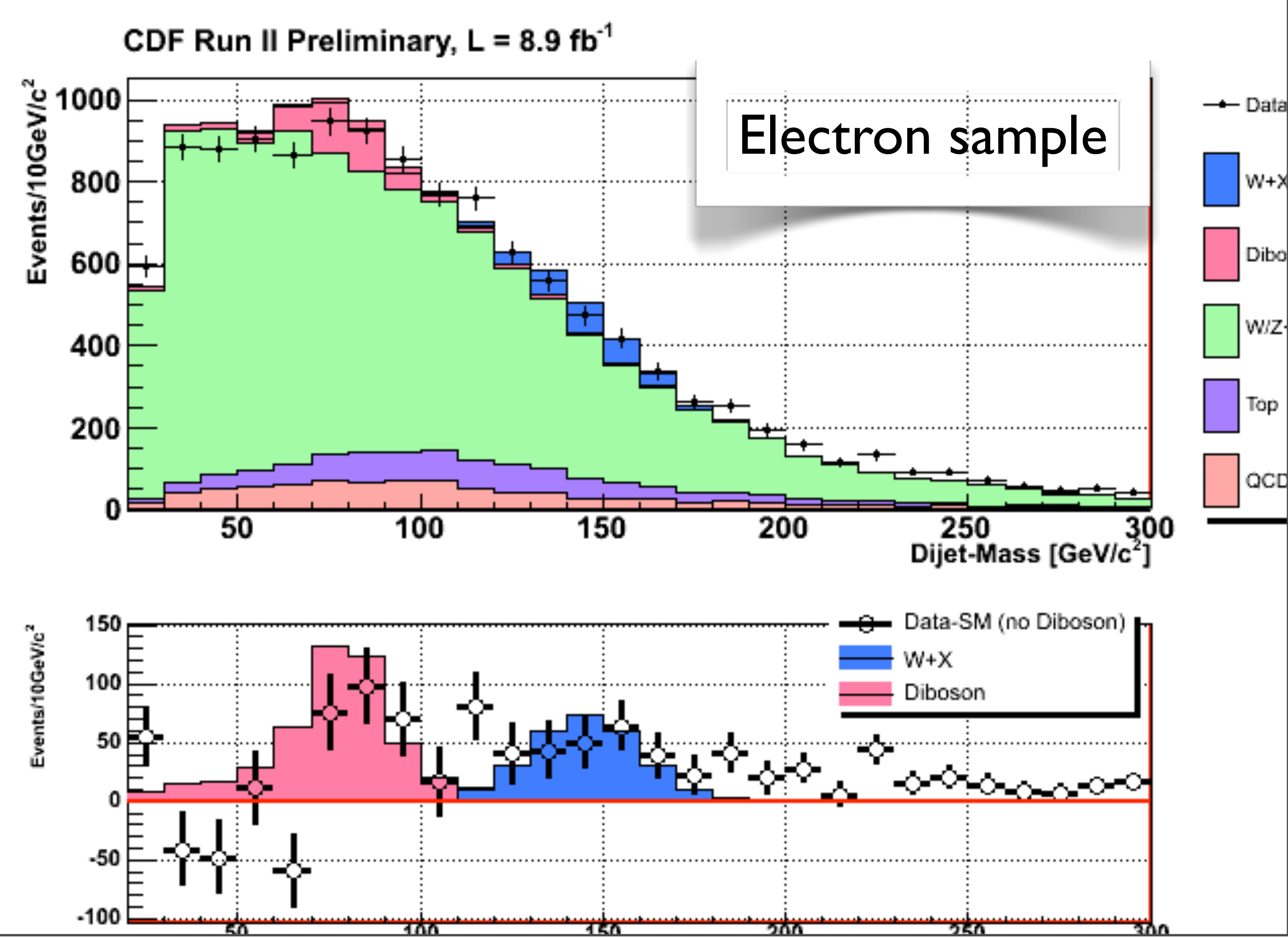


Our updated version of the excess

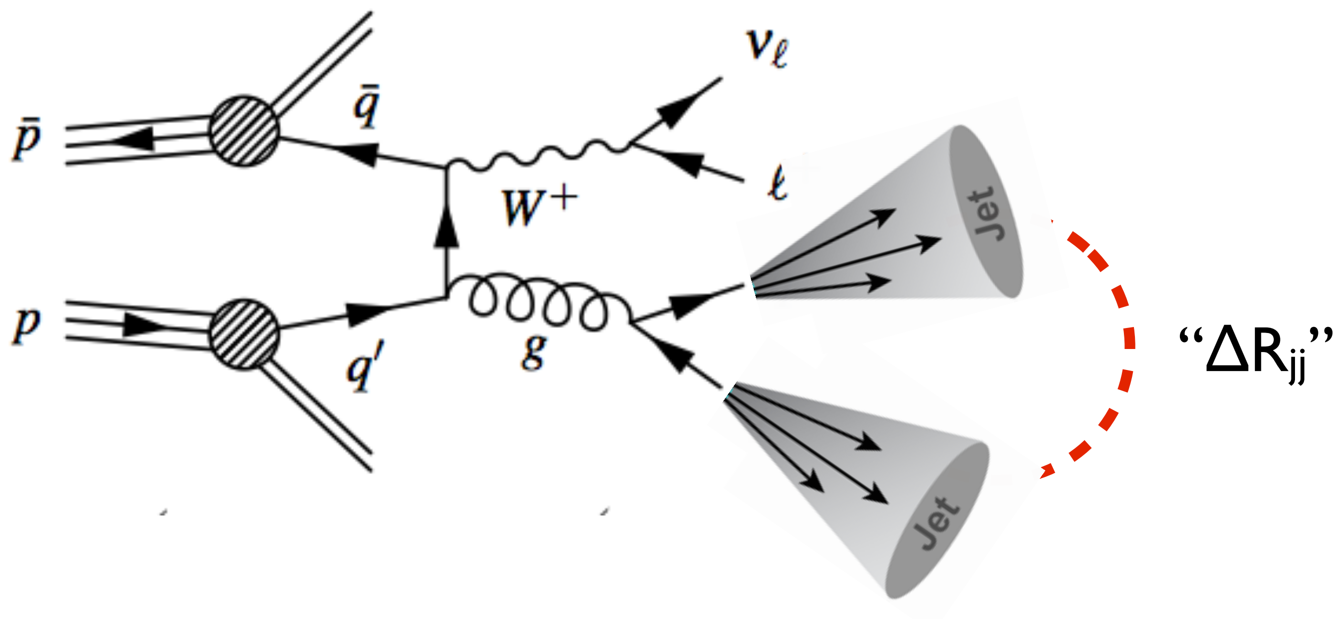


We also look at the muon and electron samples separately

Similar effects in both samples



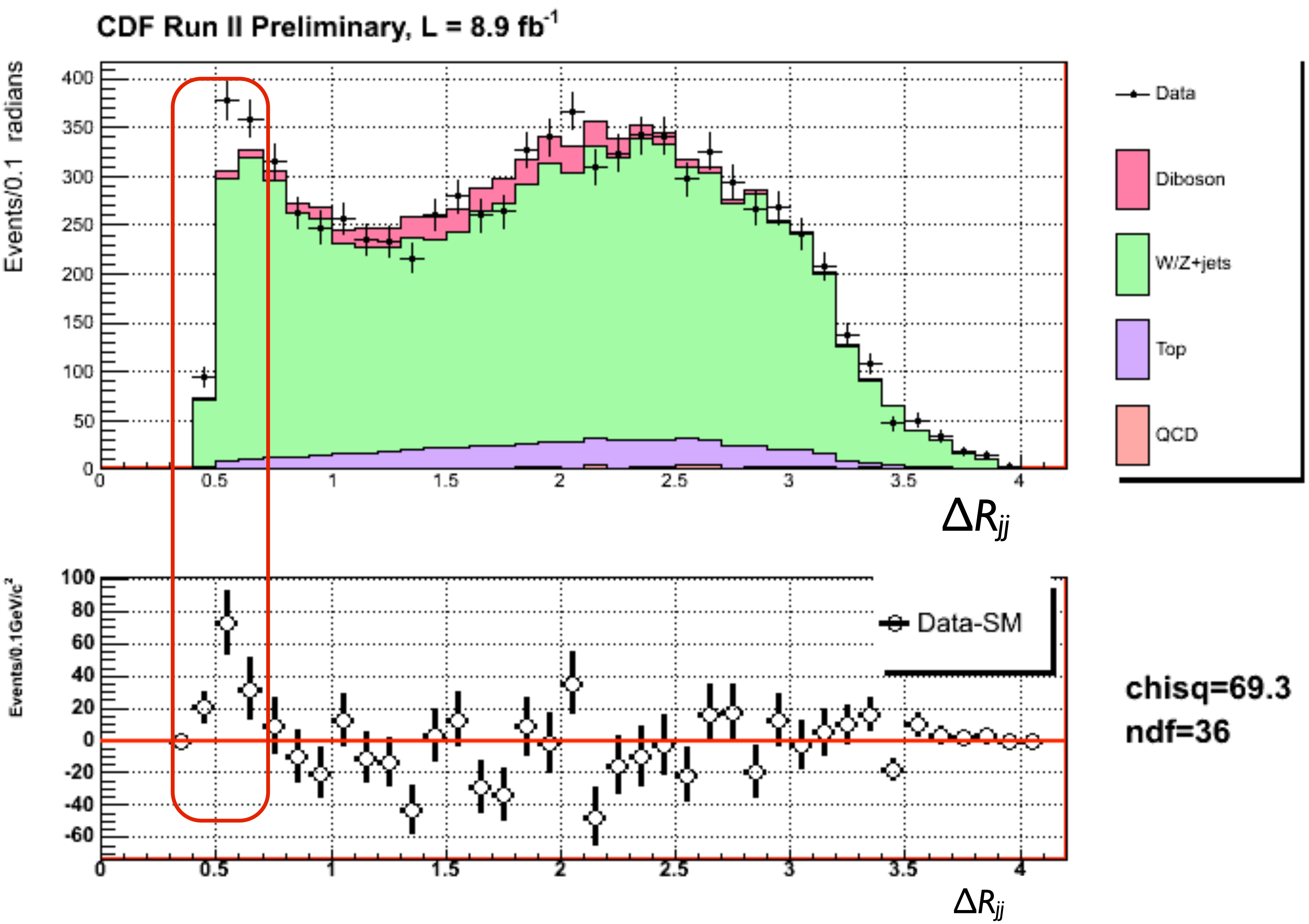
- Modeling of events with small dijet opening angle



- Modeling of the jet response
- Modeling of the fake-leptons

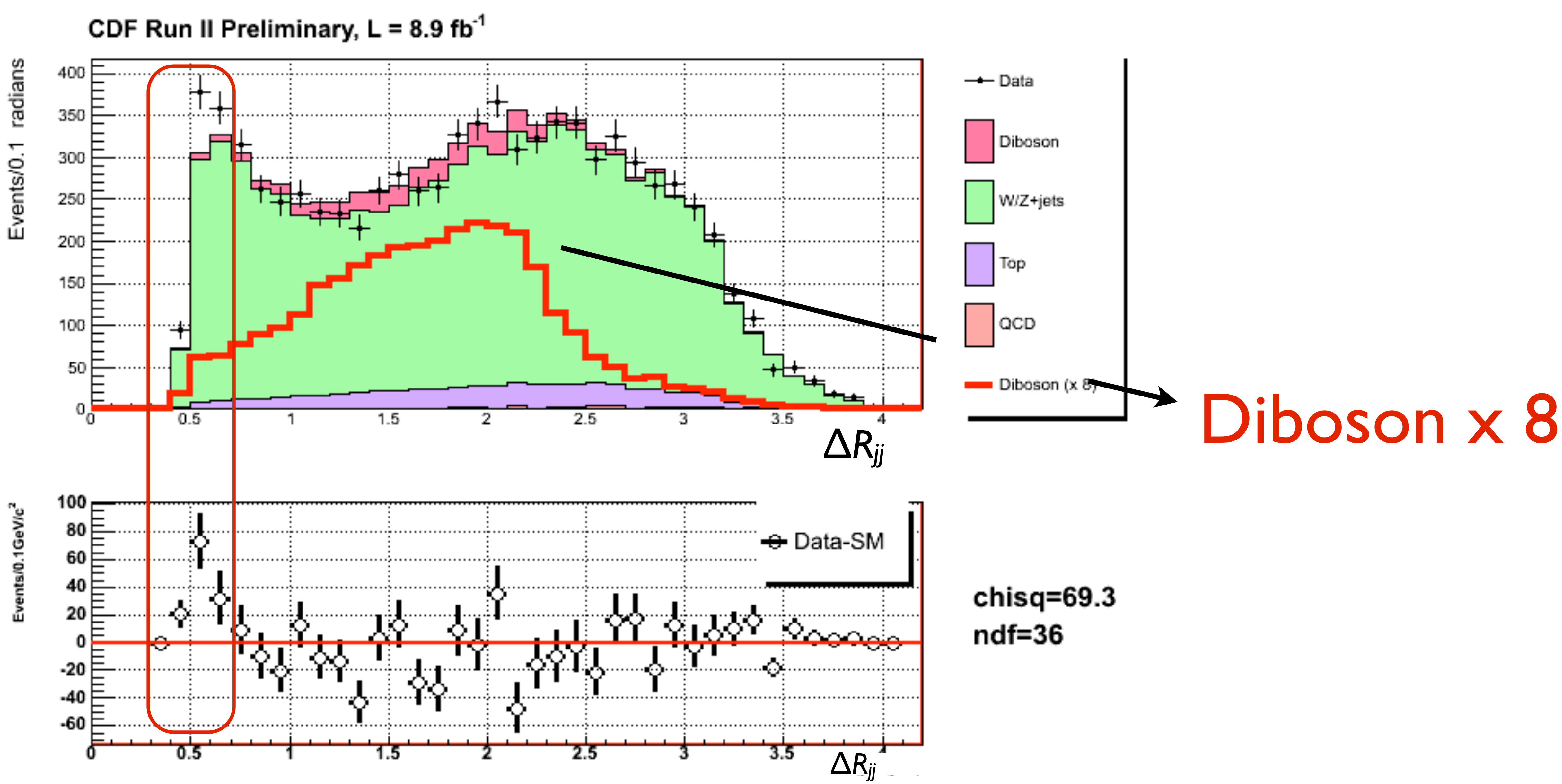
Event selection: Additional cut

- We noticed disagreements between data and predictions at low dijet opening angles
  - Clustering not properly simulated for closely spaced jets?



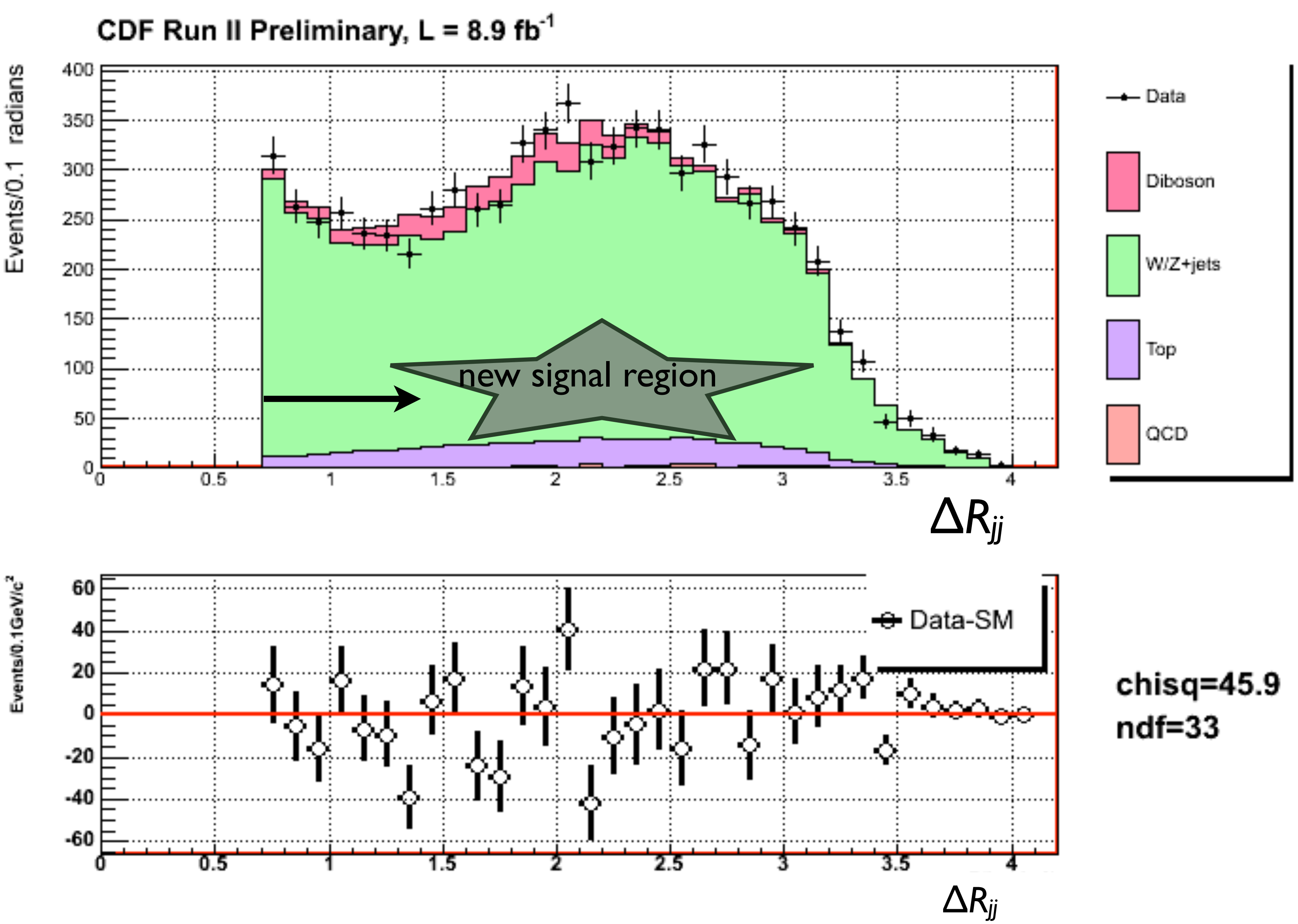
Event selection: Additional cut

- We noticed disagreements between data and predictions at low dijet opening angles
  - Clustering not properly simulated for closely spaced jets?
  - However, heavy particles decay to jets with large opening angle



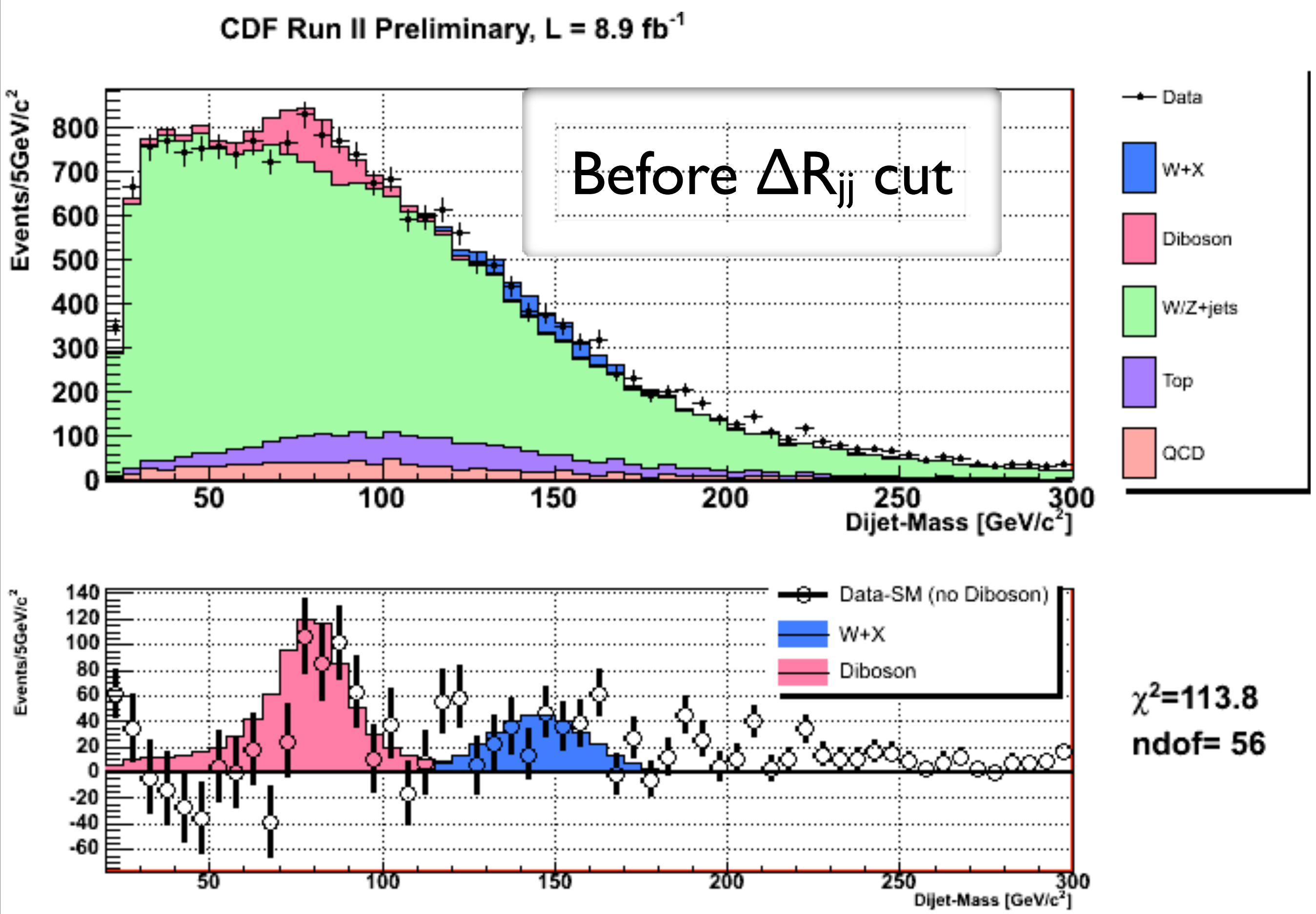
Event selection: Additional cut

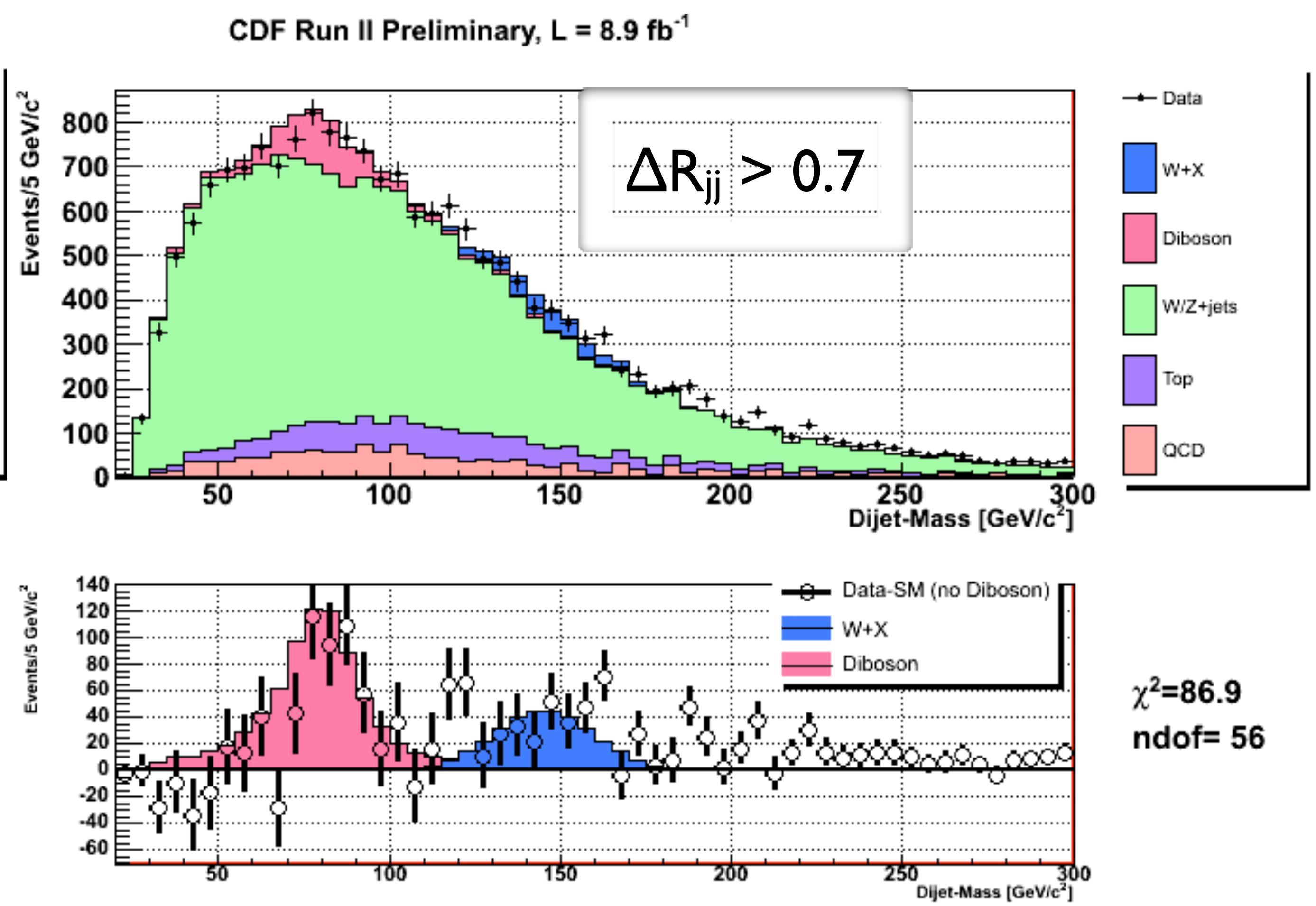
- We noticed disagreements between data and predictions at low dijet opening angles
  - Clustering not properly simulated for closely spaced jets?
  - However, heavy particles decay to jets with large opening angle
  - We therefore require $\Delta R_{jj}>0.7$



Event selection: Additional cut

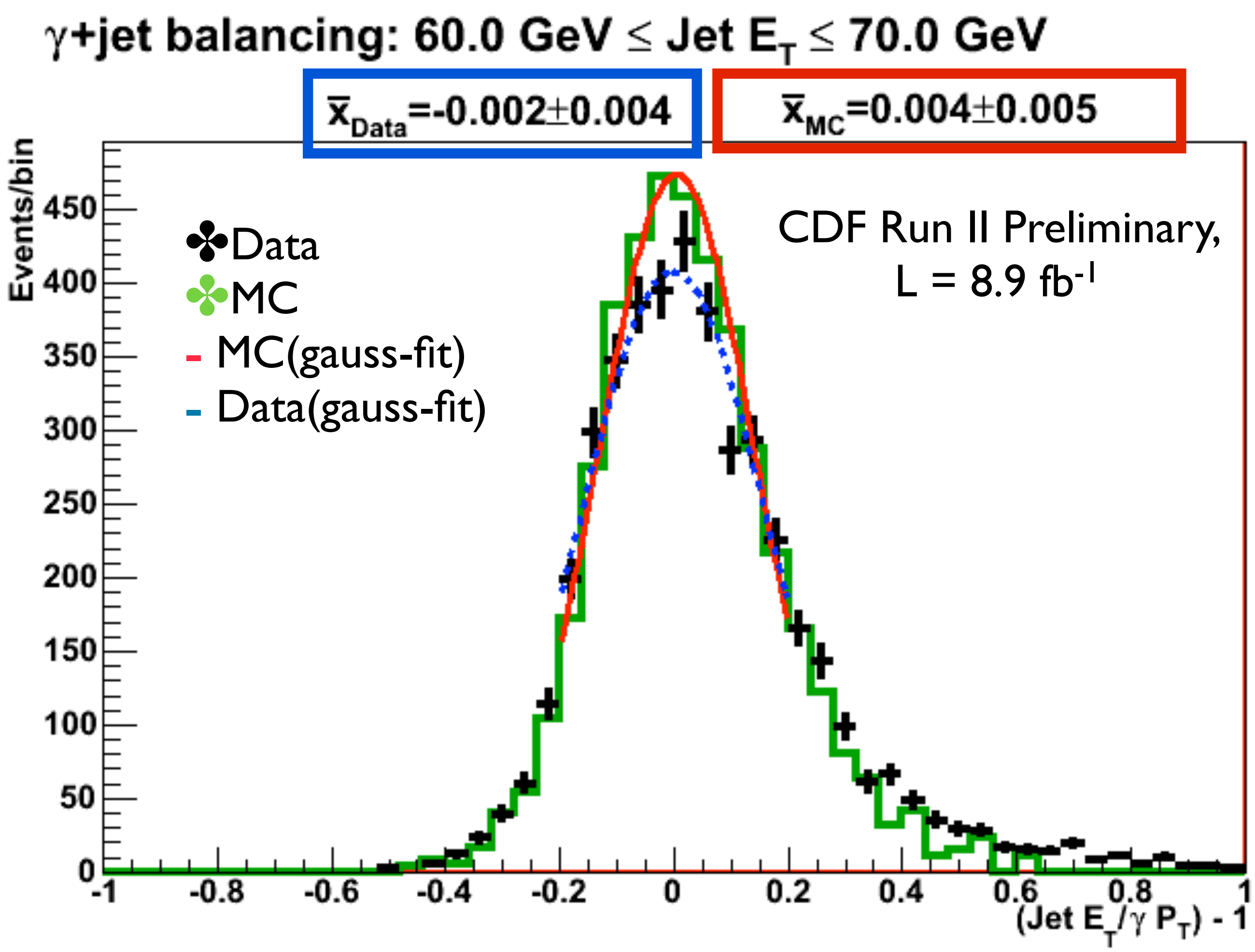
- $\Delta R_{jj}>0.7$ cut has a minor effect at large dijet masses
- But improved agreement with the predictions for low dijet masses





Object identifications - jets

- Critical to this analysis when validating the JES is the **compatibility between Data and MC**



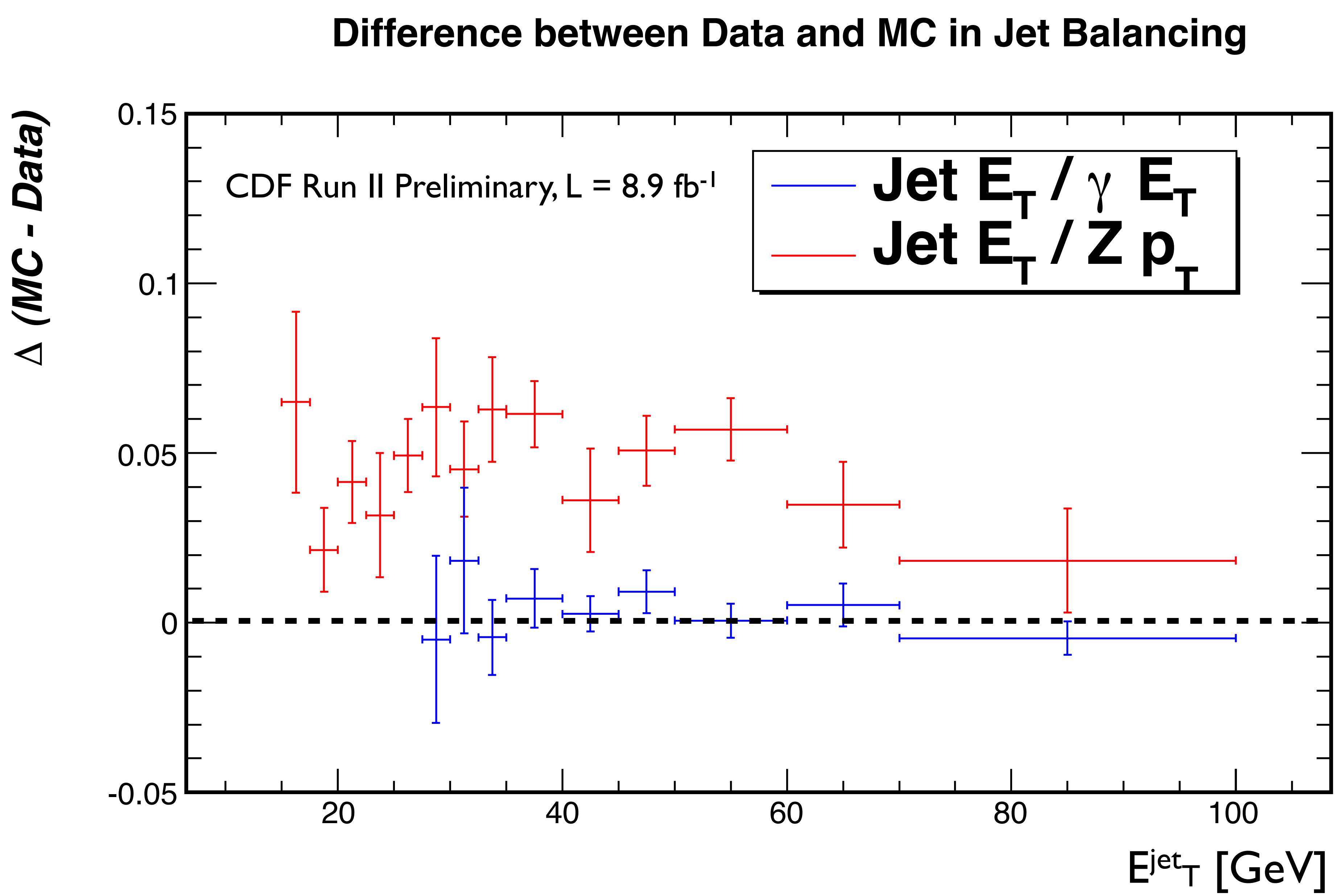
✓Jet balancing against the photon is **compatible** between PYTHIA Tune A **MC** and **Data** within statistical uncertainty

Object identifications - jets

NEW

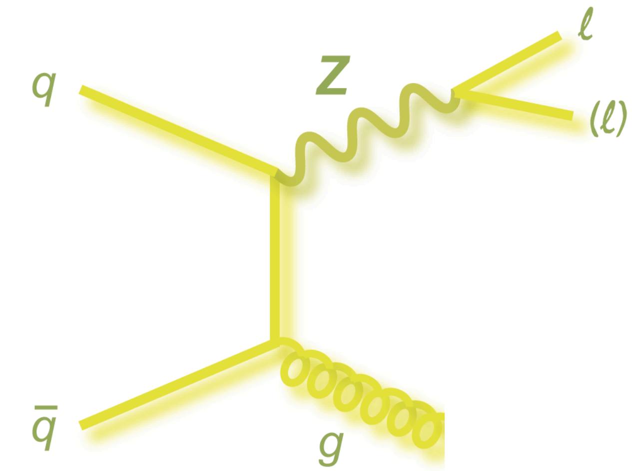
Jet balancing overview

- Balancing performed in several jet E_T bins

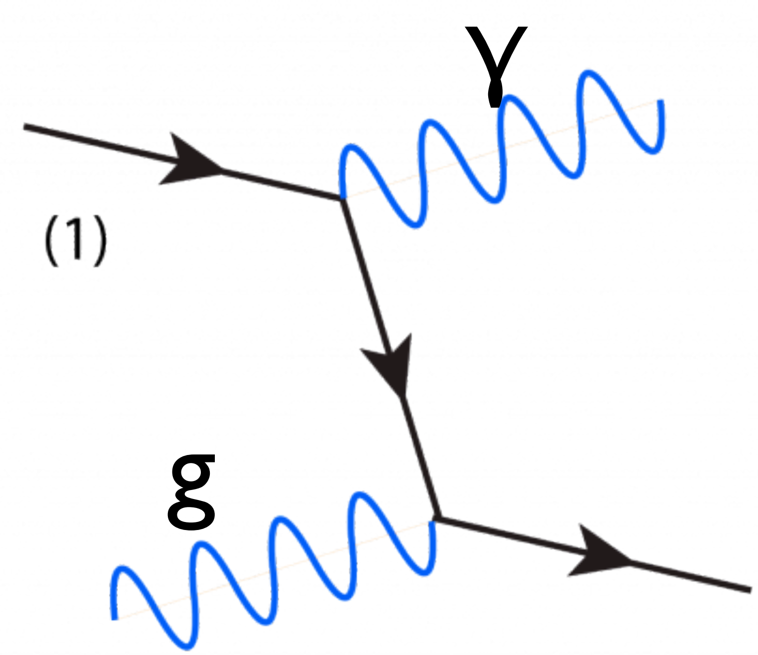


Q/G-JES: Event selection

- **Z+jet selection:**
  - PT(lep1)>20 GeV/c
  - PT(lep2)>20 GeV/c
  - 76<(M(lep1,lep2)/GeV/c2)<106
  - PT(lep1,lep2)>10 GeV/c
  - MET<20 GeV
  - =1 jet with ET>3 GeV/c
  - $\Delta\varphi$(jet,Z)>2.8



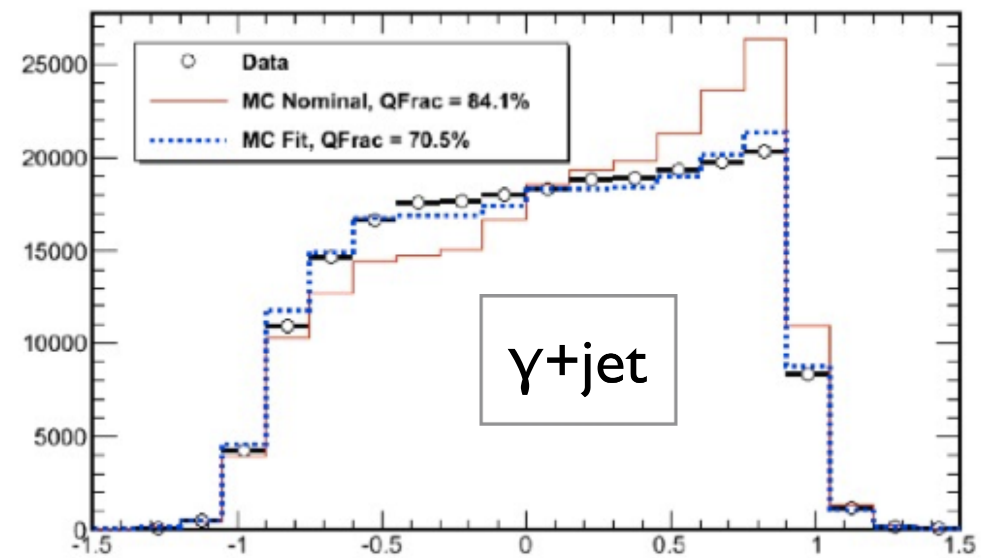
- **γ+jet selection:**
  - ET^{γ}> 27 GeV, 0.2<|η|<0.6
    - away from cracks in the calorimeter and trigger biases
  - =1 number of primary vertices
  - MET/ET^{γ}<0.8
  - =1 jet with ET>3 GeV/c
  - $\Delta\varphi$(jet,γ)>3

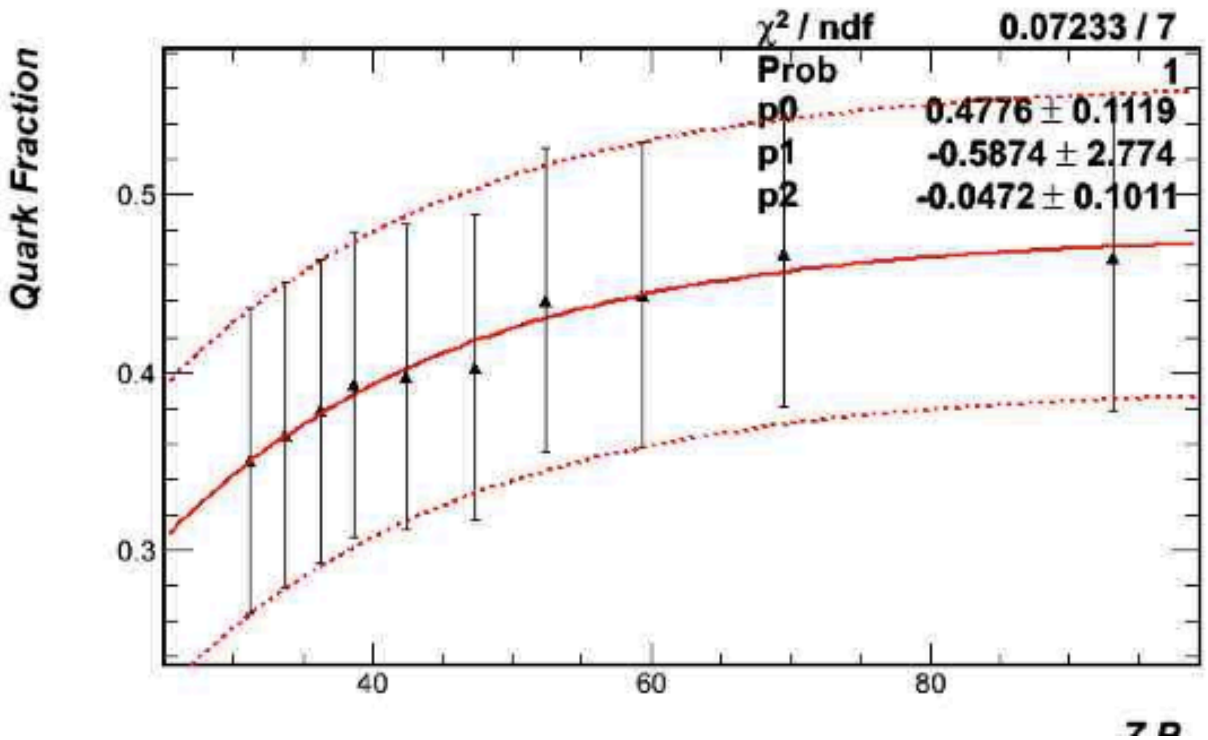


Inputs to Q/G-JES: F^Q

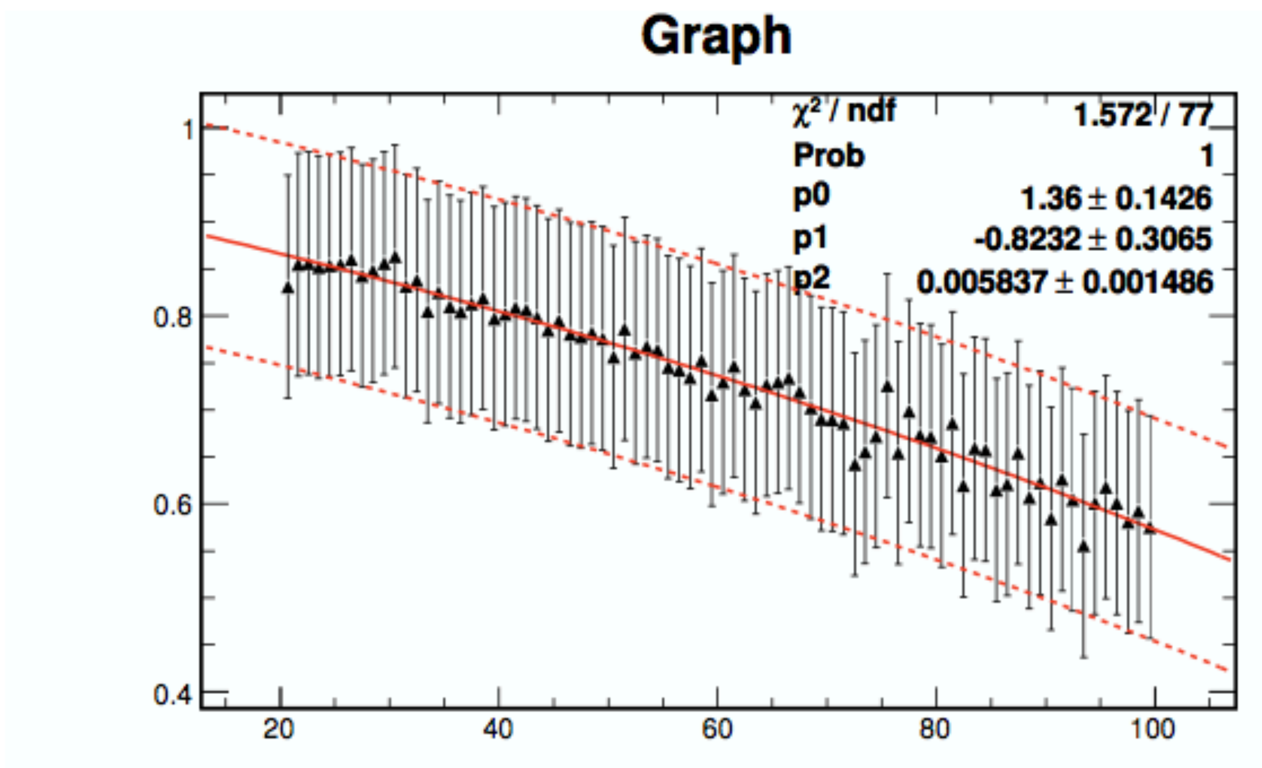
- Predicted from MC (at first order)

- Cross-checked with the data
  - We developed quark-gluon discriminant is an artificial neural network discriminant that examines the shape of a jet and assigns a score based on how quark-like the jet appears to be An artificial
  - Fit the quark-gluon discriminant distribution with quark and gluon templates from MC
  - The obtained difference with the predicted F^Q is <~ 10%
    - used as systematic uncertainties when when deriving quark/gluon JES





χ^2 / ndf 0.07233 / 7
Prob 1
p0 0.4776 ± 0.1119
p1 -0.5874 ± 2.774
p2 -0.0472 ± 0.1011
Quark Fraction
0.5
0.4
0.3
40
60
80

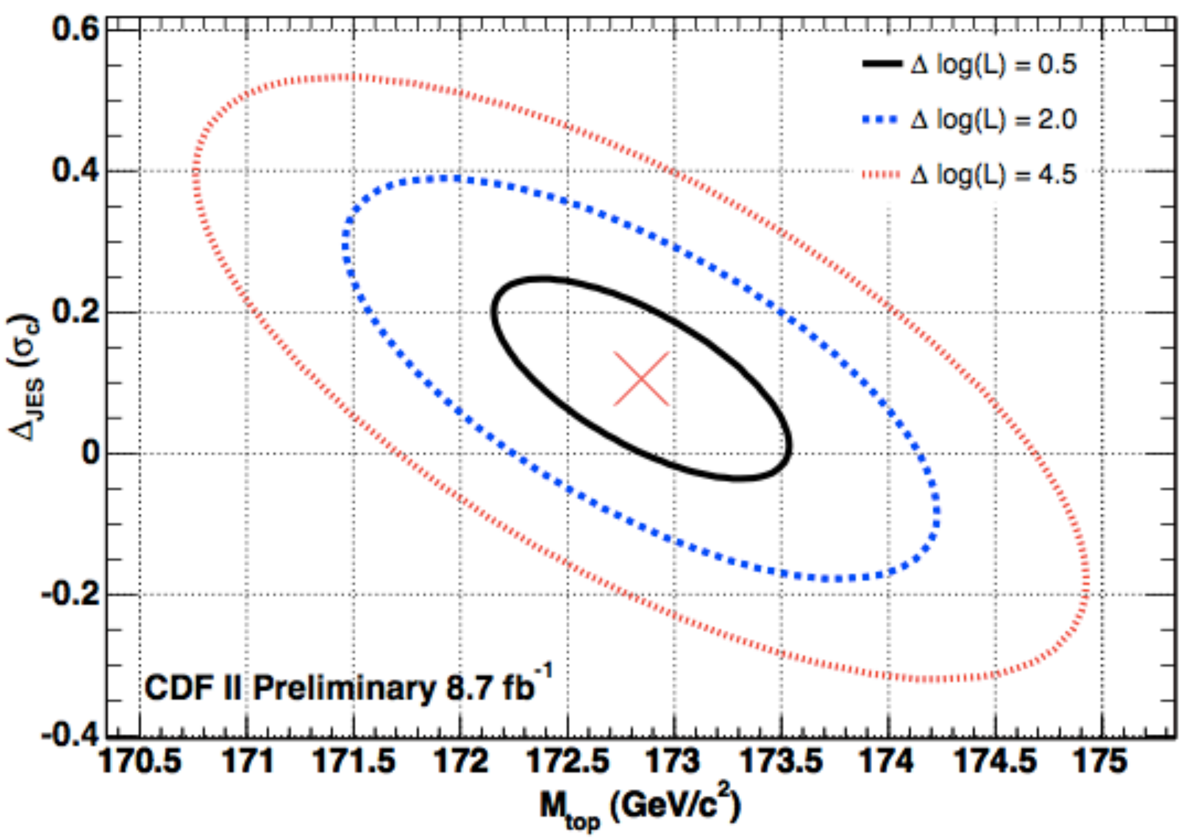


Graph
χ^2 / ndf 1.572 / 77
Prob 1
p0 1.36 ± 0.1426
p1 -0.8232 ± 0.3065
p2 0.005837 ± 0.001486
1
0.8
0.6
0.4
20
40
60
80
100

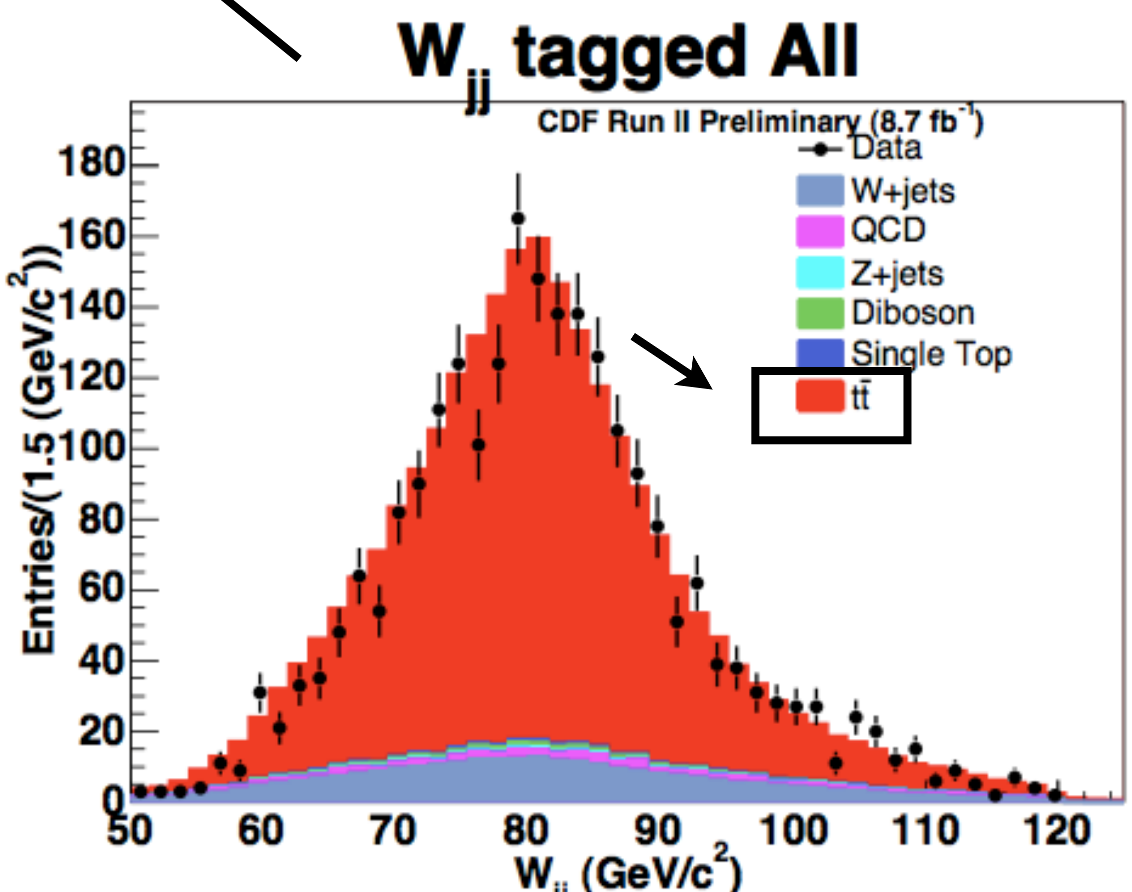
Quark Vs gluon JES ("Q/G-JES")

Why not before (Additional reasons)?

- Never encountered any problems in the main investigated samples
    - top-pairs enhanced samples are heavily quark-dominated



CDF Note 10749
Hyun-su Lee *et al.*



Effect of the changes on main analyses @CDF

3. QCD:

- cross-section analyses use R=0.7 cone-MIDPOINT or antiKT jets
  - those algorithms are less sensitive to soft radiation
  - Data-MC discrepancy even for JETCLU R=0.7 cone jets is within CDF JES uncertainty

NIM A 622 (2010) 698-710

Source of uncertainty	jet cone = 0.4	jet cone = 0.7	jet cone = 1.0
renormalization and factorization scales	+0.9 -0.0	+0.9 -0.4	±0.4
FSR parameters in PYTHIA	±0.4	±0.1	±0.1
ME's and parton-jet matching	+0.8 -0.0	+1.1 -0.0	+0.8 -0.0
single particle response	±2.5	±2.5	±2.5
multiple proton interactions	+1.0 -0.0	+1.2 -0.0	+1.2 -0.0
large-angle FSR, limitation of PS	+0.0 -2.9	+0.0 -0.2	+1.7 -0.0
Estimate of the total variation	+3.0 -3.8	+3.1 -2.5	+3.4 -2.5
The observed discrepancy *	+4.7	+3.2	+2.0

*: the observed discrepancy is defined as the P_T imbalance (P^{jet}_T / P^{Z}_T) in predictions divided by Z+1jet data

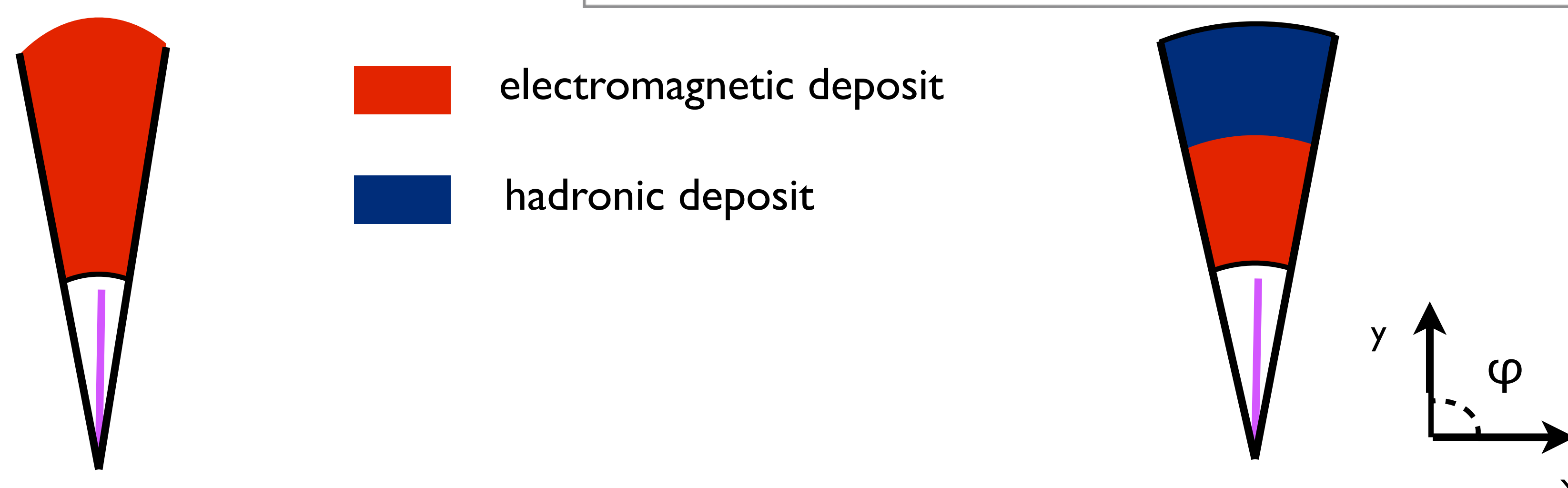
QCD multi-jets background

- *Quick Reminder:* differences between electron candidates and non-electrons

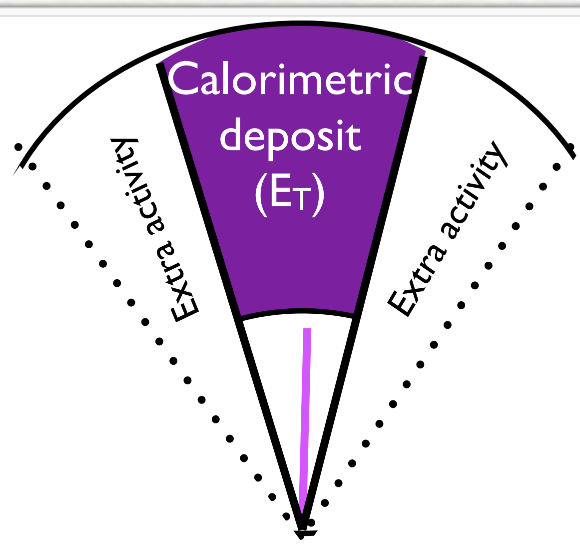
Electron candidate

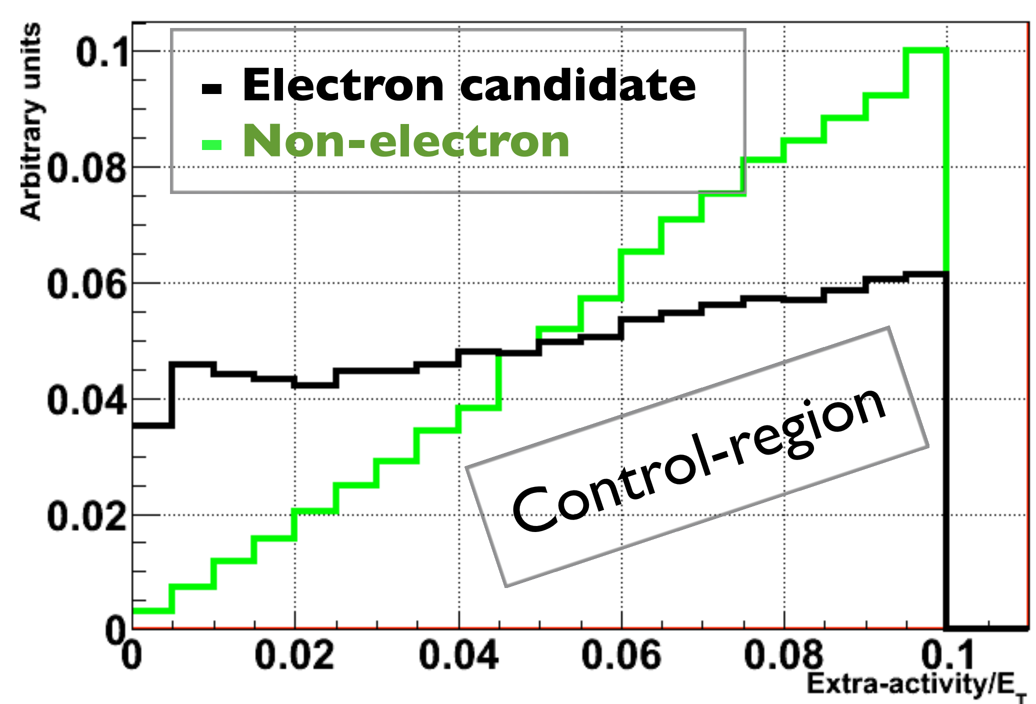
Non-electron
(failing two identification requirements)

1. Electromagnetic fraction



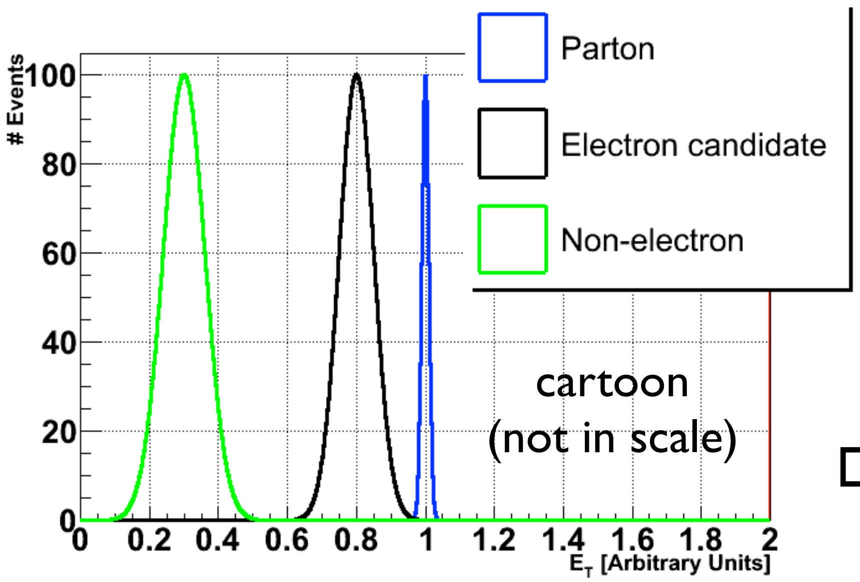
2. Extra activity outside the calorimetric cluster

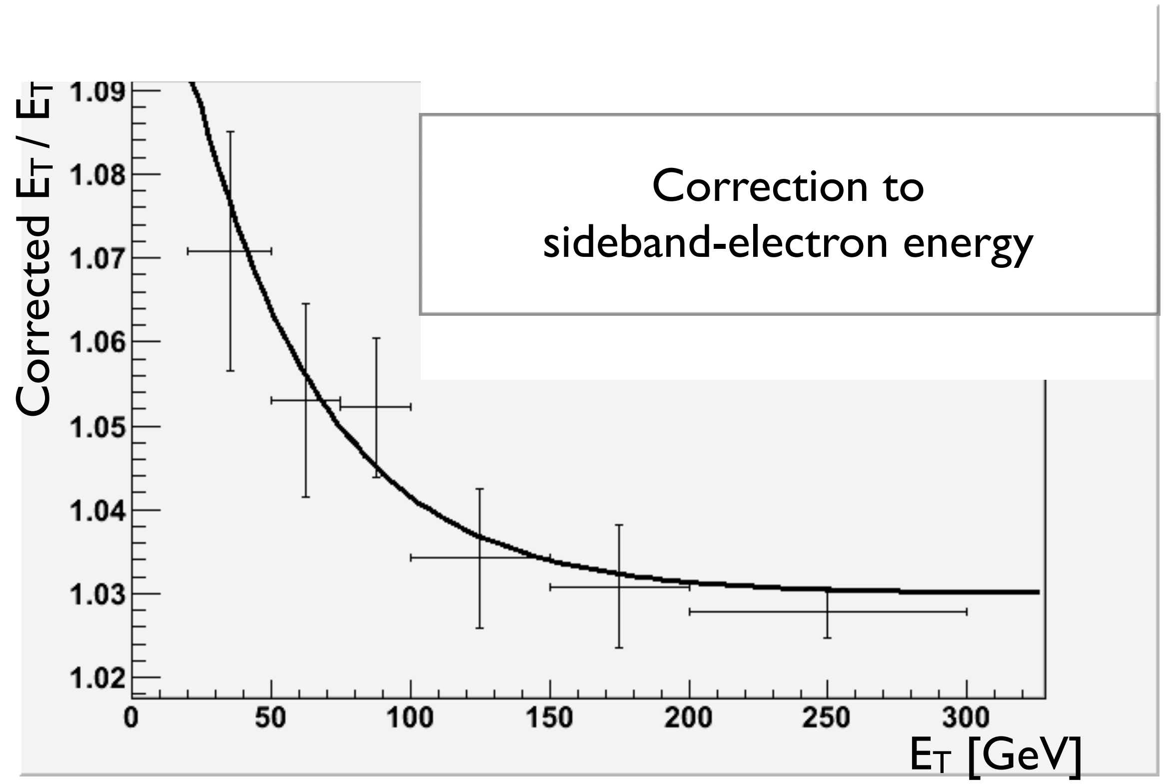


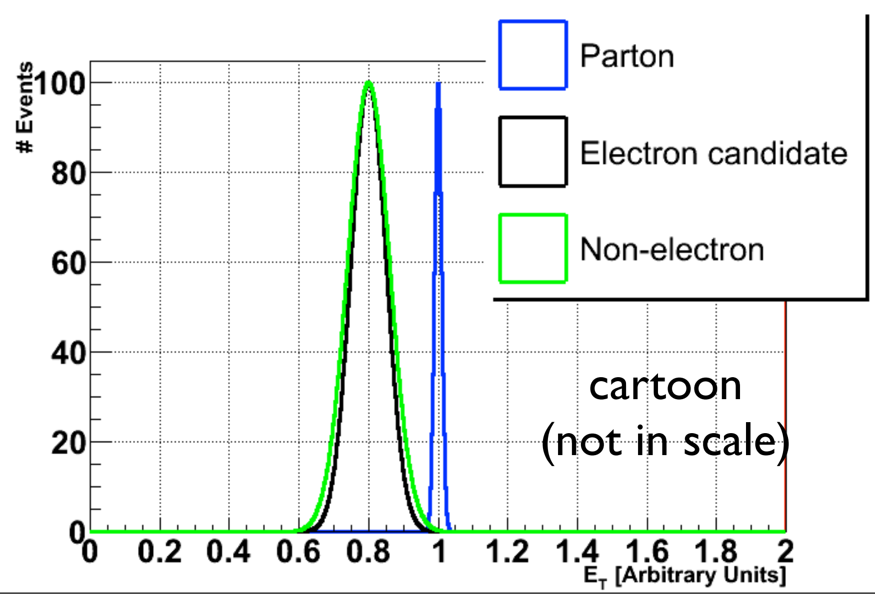


QCD multi-jets background

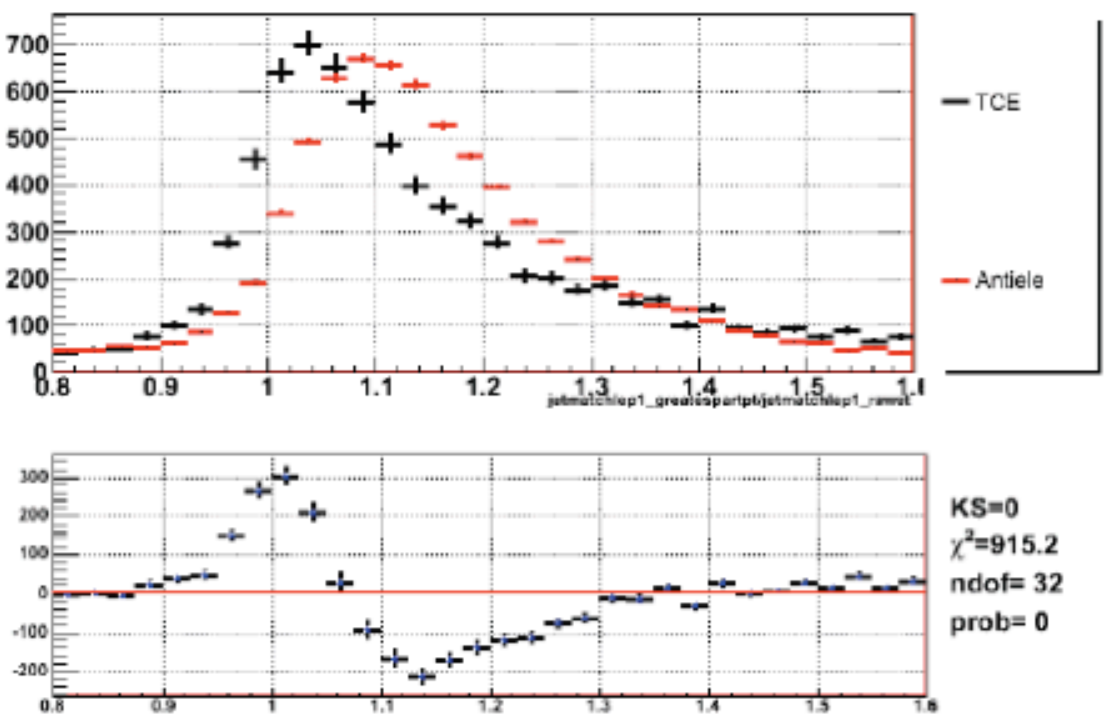
- *Question*: given the same parton energy, does non-electron energy properly model candidate-electron energy?
- *Answer*: from MC we see that non-electron energy needs to be corrected



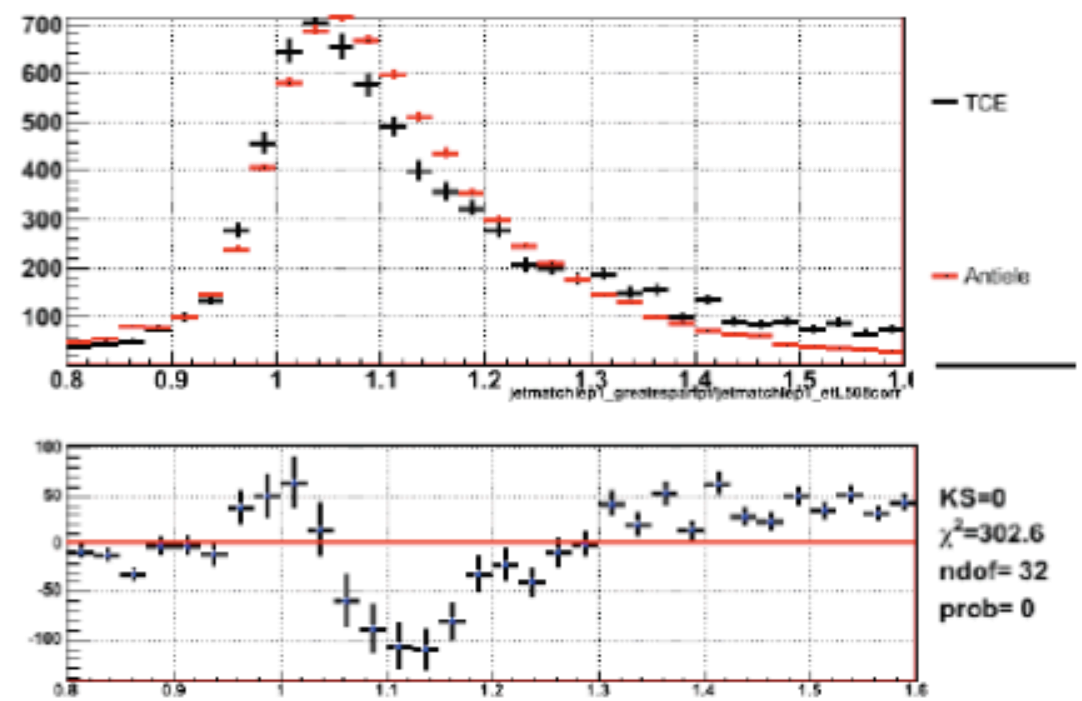




Corrections for non-electron energies: 3-8%

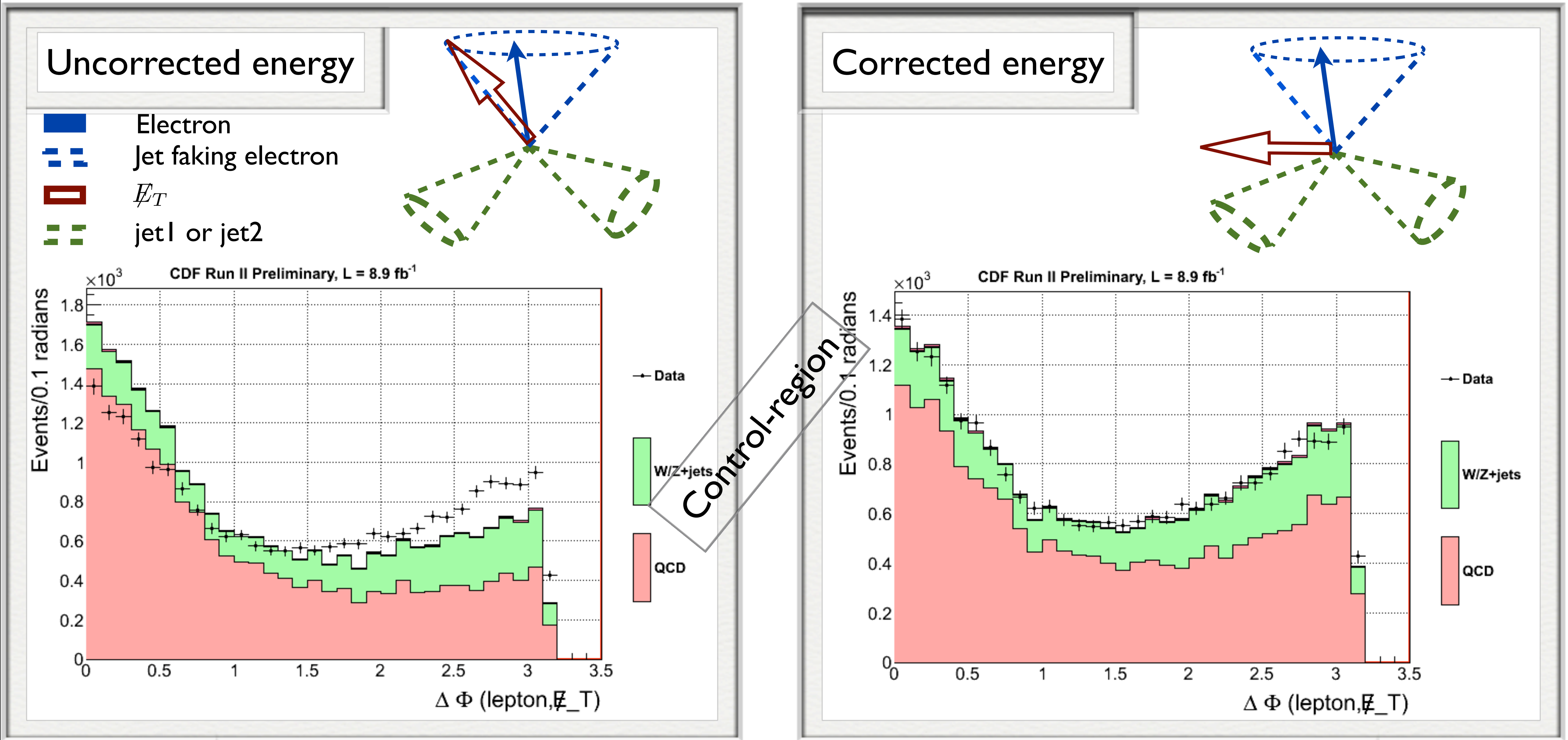


jmlrawet^{Antiele}*K



QCD multi-jets background

- Validation of the non-electron energy corrections
  - **Note**: Corrections affect the magnitude and the direction of the missing transverse energy



Large improvements when corrections are applied

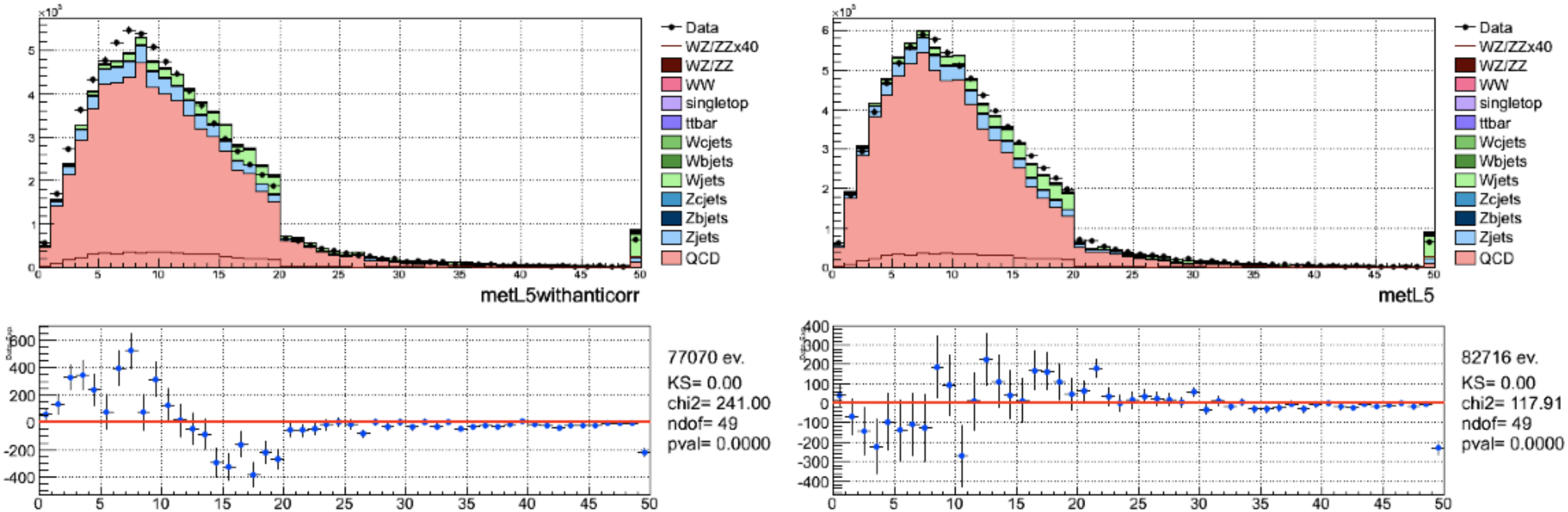


Figure 14: *$\not{E}_T$ with out-of-the-box (left) and cured (right) QCD model.*

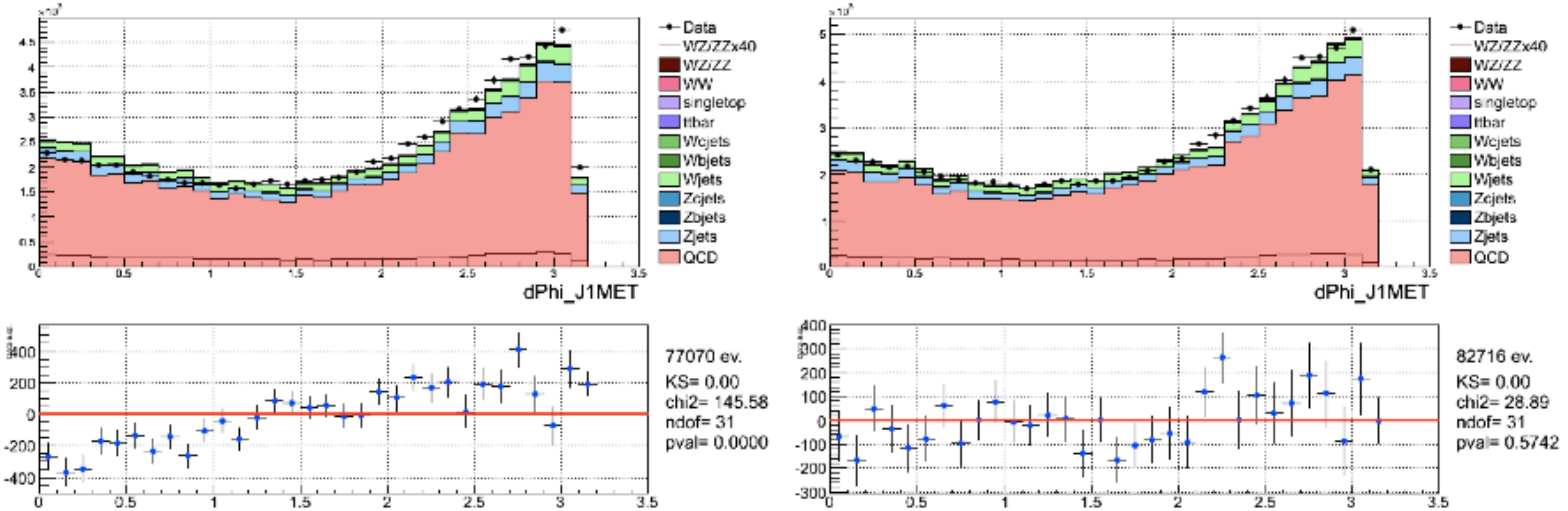
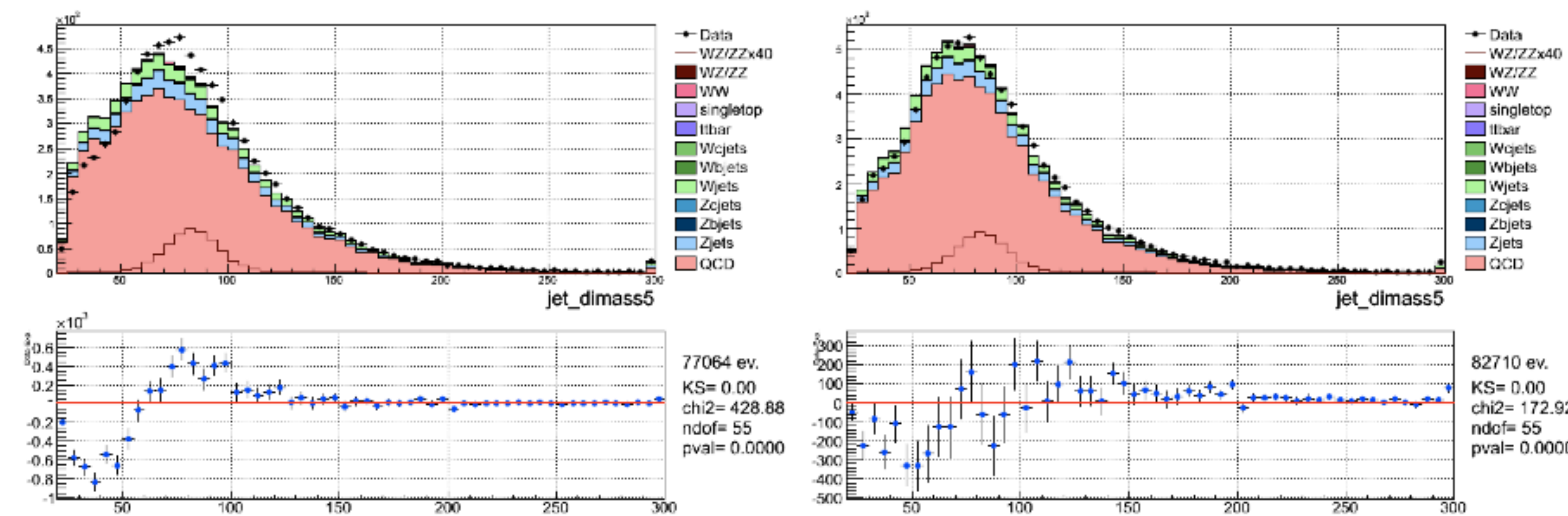
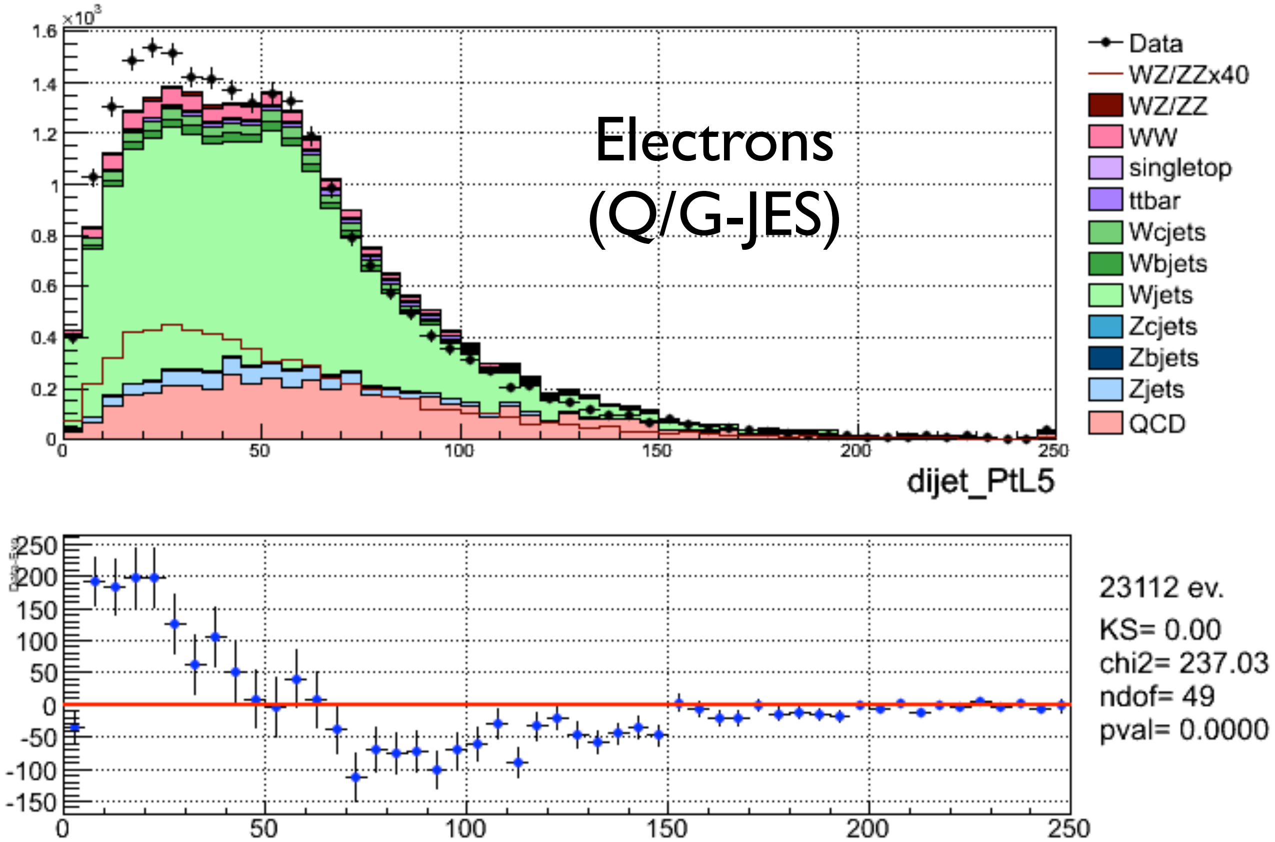


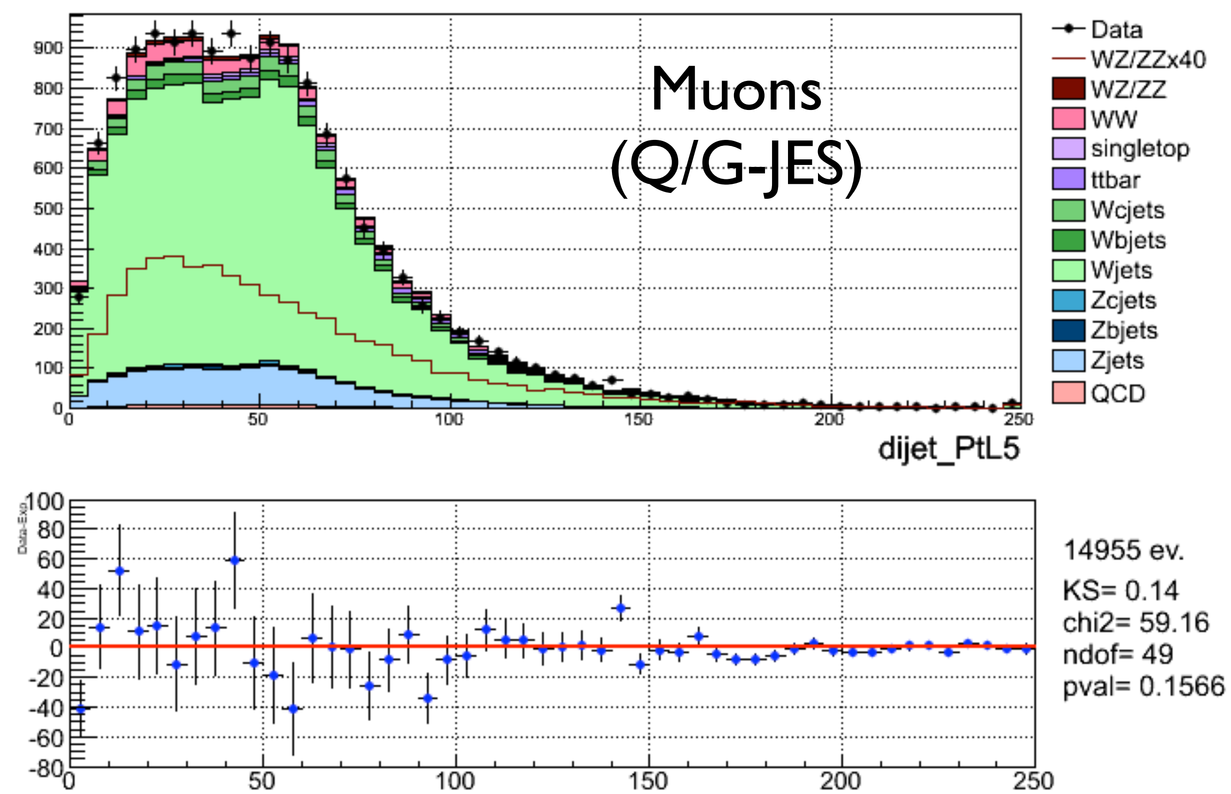
Figure 18: *dPhi(jet1,$\not\!\!E_T$) with out-of-the-box (left) and cured (right) QCD model.*



Modeling in the electron sample

- For a more accurate evaluation
  - P_T(jet1,jet2) cut is removed
  - jet ET cuts are lowered to 20 GeV (was 30 GeV)
- Electron and muon samples are compared

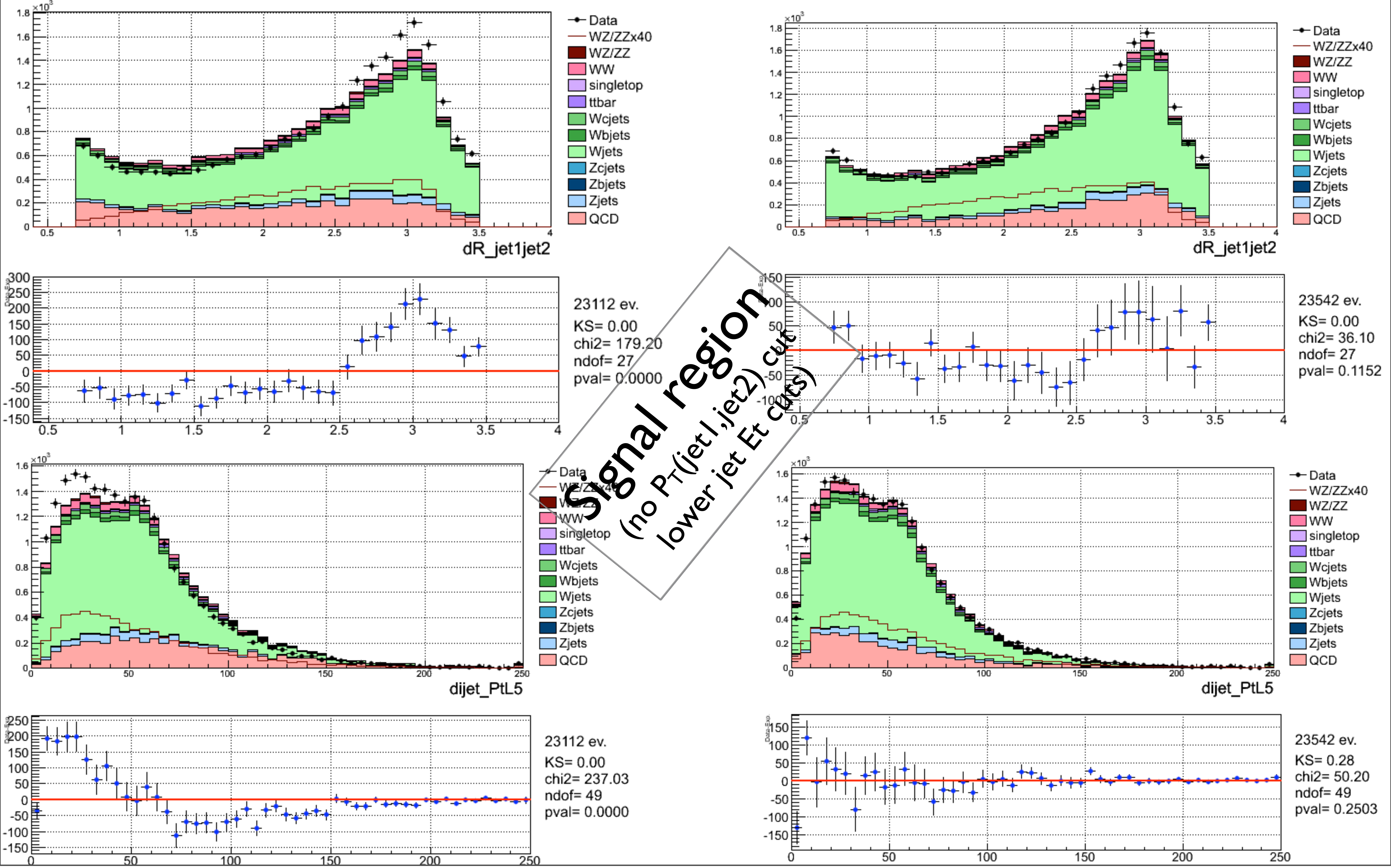


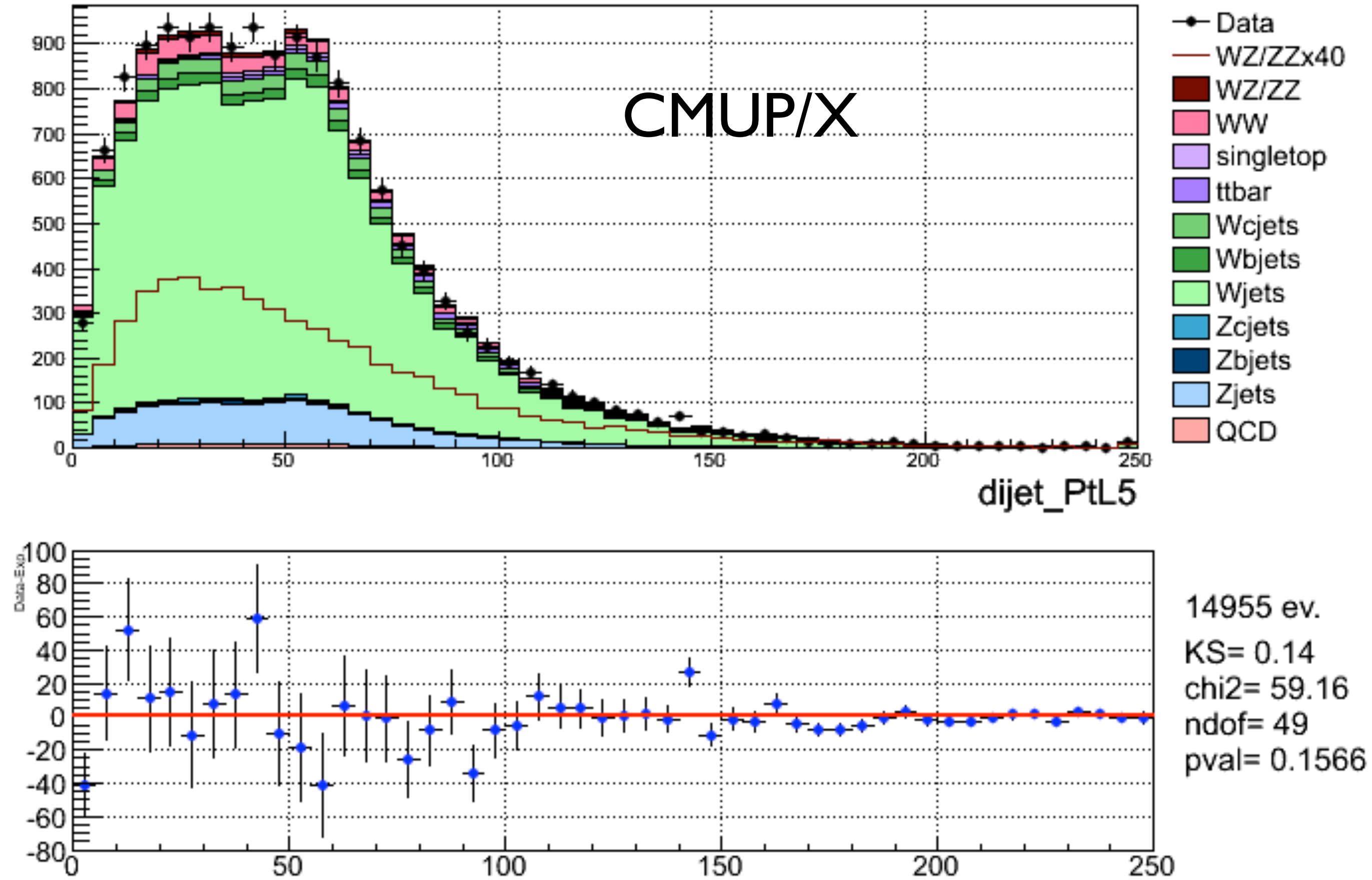


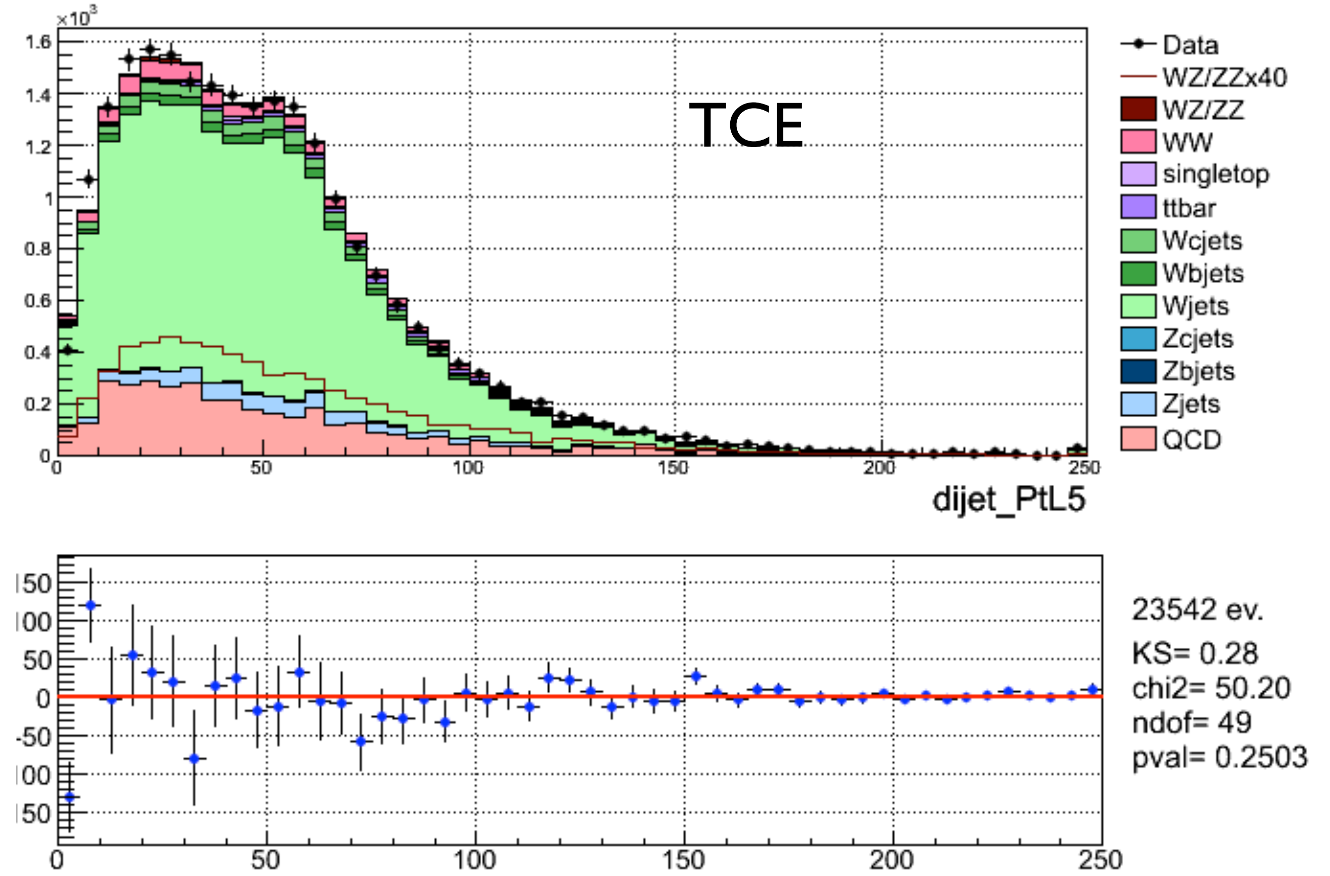
- Large mismodeling at low P_T(jet1,jet2) in the electron sample as opposed to the muon sample

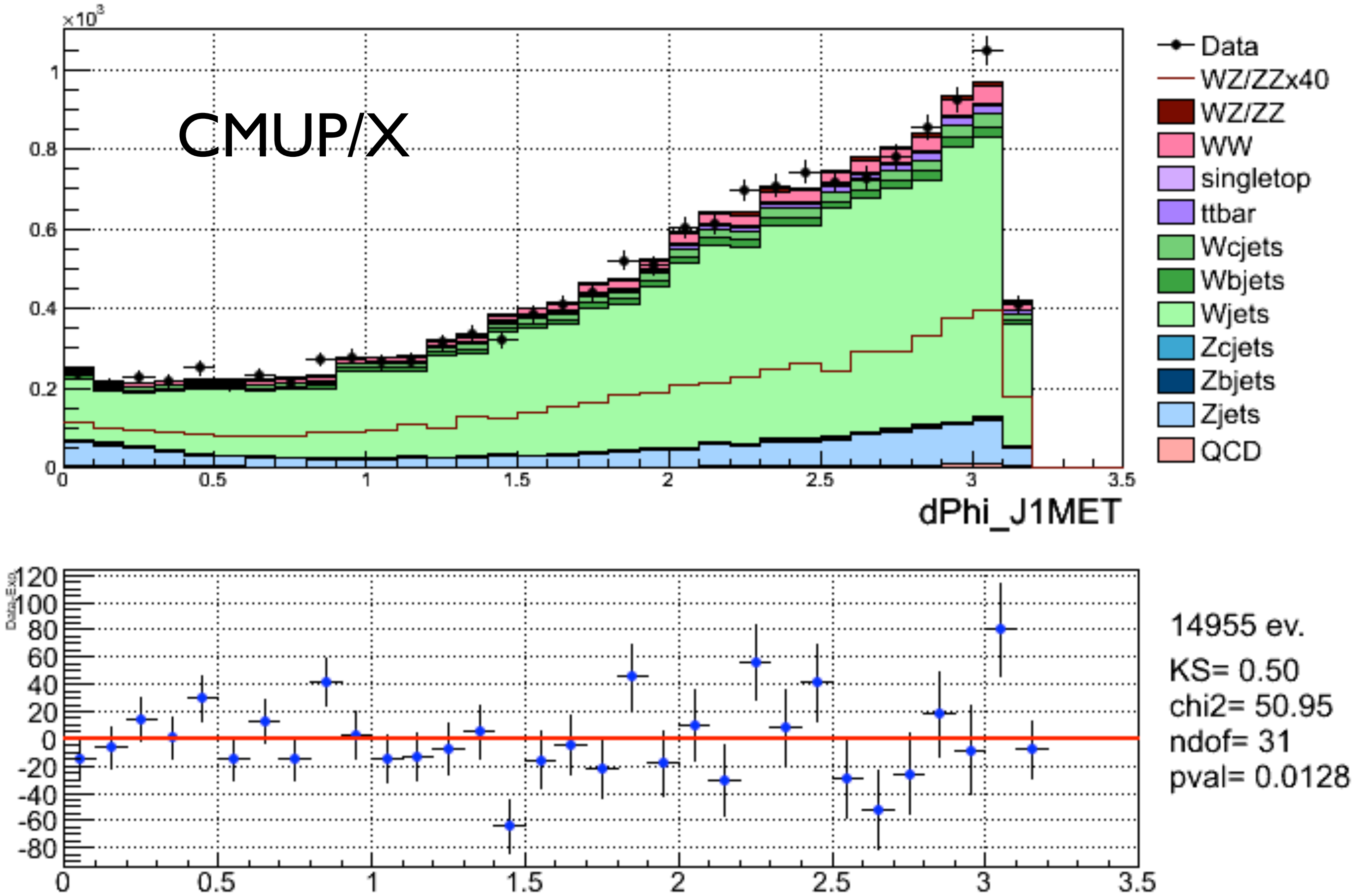
QCD model before and after the cure - Diboson selection

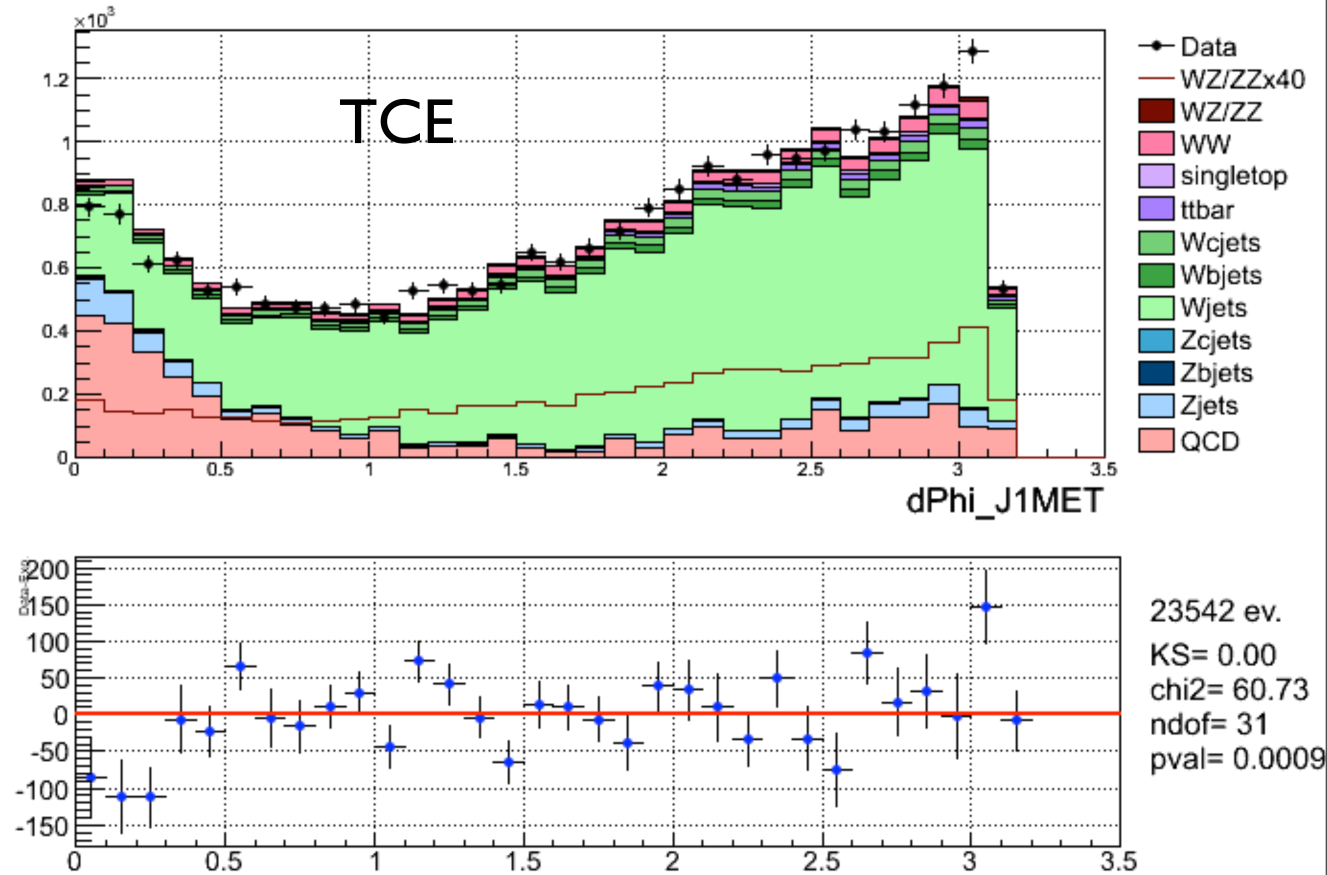
- Modeling with the QCD model before (left) and **after correcting the antielectron energy and removing the trigger bias** (right)




CMUP/X
Data
WZ/ZZx40
WZ/ZZ
WW
singletop
ttbar
Wcjets
Wbjets
Wjets
Zcjets
Zbjets
Zjets
QCD
dijet_PtL5
14955 ev.
KS= 0.14
chi2= 59.16
ndof= 49
pval= 0.1566


TCE
Data
WZ/ZZx40
WZ/ZZ
WW
singletop
ttbar
Wcjets
Wbjets
Wjets
Zcjets
Zbjets
Zjets
QCD
dijet_PtL5
23542 ev.
KS= 0.28
chi2= 50.20
ndof= 49
pval= 0.2503

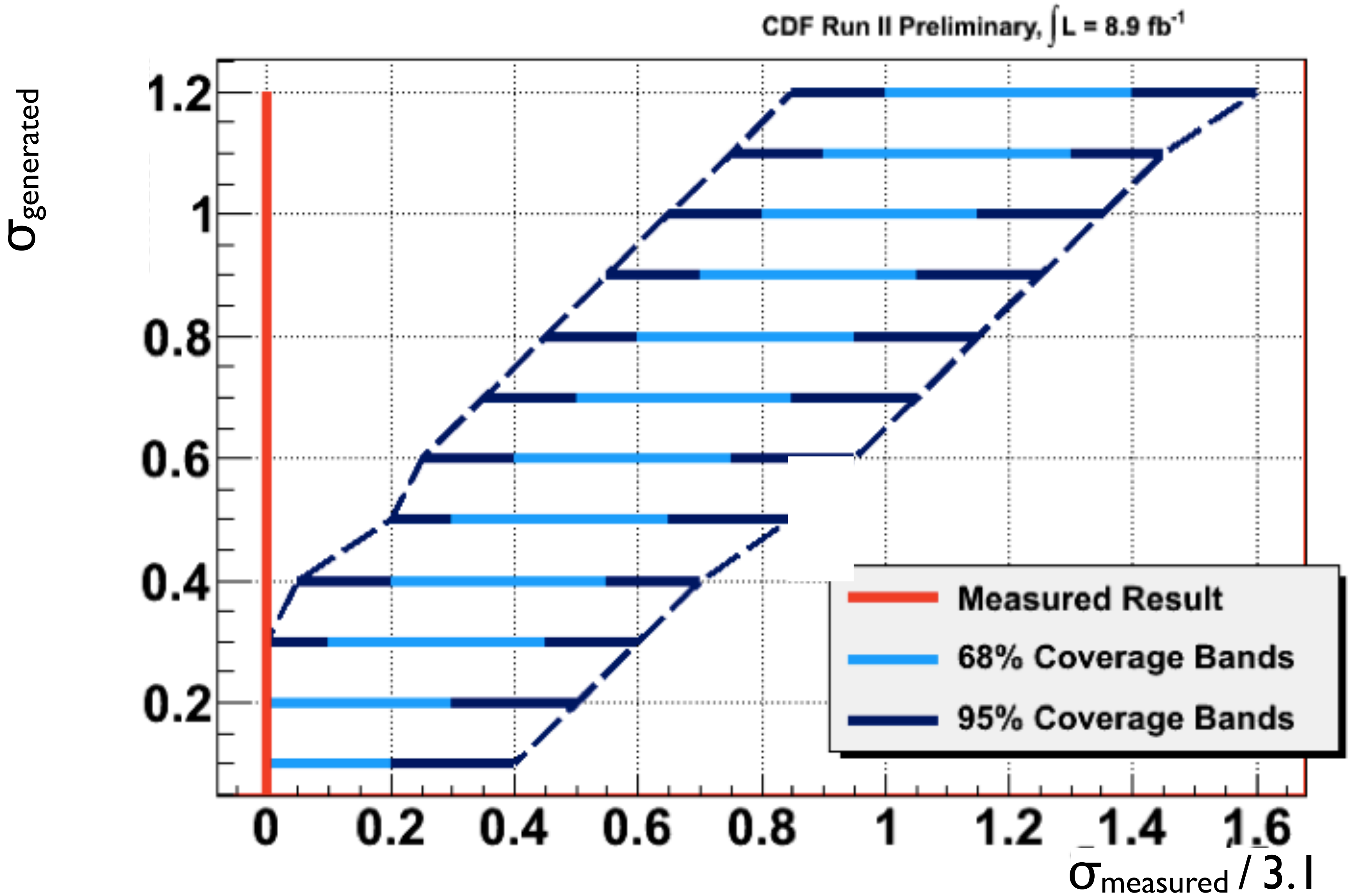

CMUP/X
Data
WZ/ZZx40
WZ/ZZ
WW
singletop
ttbar
Wcjets
Wbjets
Wjets
Zcjets
Zbjets
Zjets
QCD
dPhi_J1MET
14955 ev.
KS= 0.50
chi2= 50.95
ndof= 31
pval= 0.0128


TCE
Data
WZ/ZZx40
WZ/ZZ
WW
singletop
ttbar
Wcjets
Wbjets
Wjets
Zcjets
Zbjets
Zjets
QCD
dPhi_J1MET
23542 ev.
KS= 0.00
chi2= 60.73
ndof= 31
pval= 0.0009

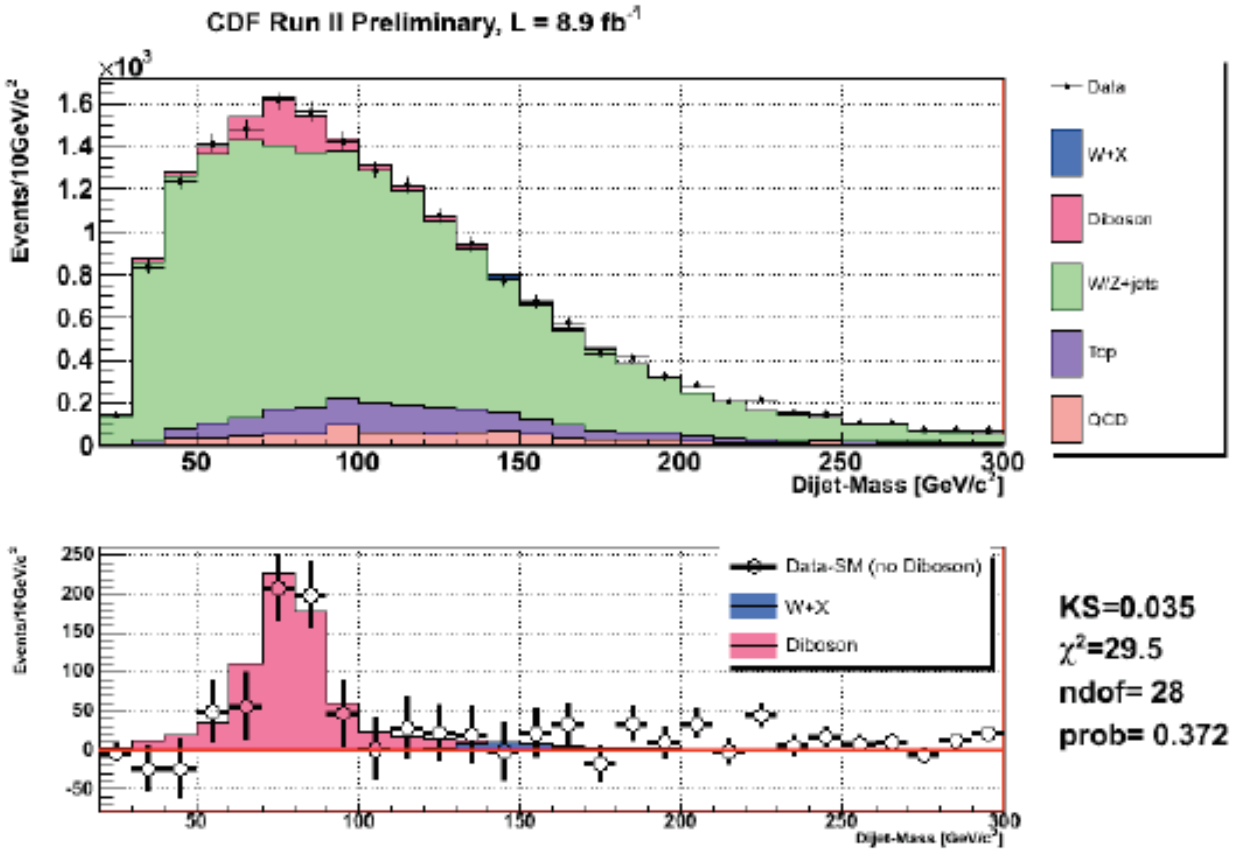
Systematic uncertainties

Systematic	WW+WZ+ZZ	Single-top	$t\bar{t}$	$W+$ jets	$Z+$ jets	QCD
JES shape/rate	yes/$\pm^{2.8\%}_{3.5\%}$	yes/$\pm^{0.2\%}_{1.8\%}$	yes/$\pm^{0.2\%}_{1.8\%}$	yes/no	yes/no	no/no
Q^2	no	no	no	yes	no	no
Luminosity	$\pm^{6.0\%}_{6.0\%}$	$\pm^{6.0\%}_{6.0\%}$	no	no	no	no
IFSR	$\pm^{2.5\%}_{2.5\%}$	$\pm^{2.5\%}_{2.5\%}$	no	no	no	no
PDF	$\pm^{2.0\%}_{2.0\%}$	$\pm^{2.0\%}_{2.0\%}$	no	no	no	no
Trigger efficiency	$\pm^{2.2\%}_{2.2\%}$	$\pm^{2.2\%}_{2.2\%}$	no	no	no	no

Since no resonance was found we establish
$\sigma < \sigma_{max}$ = 0.9 pb @ 95% CL



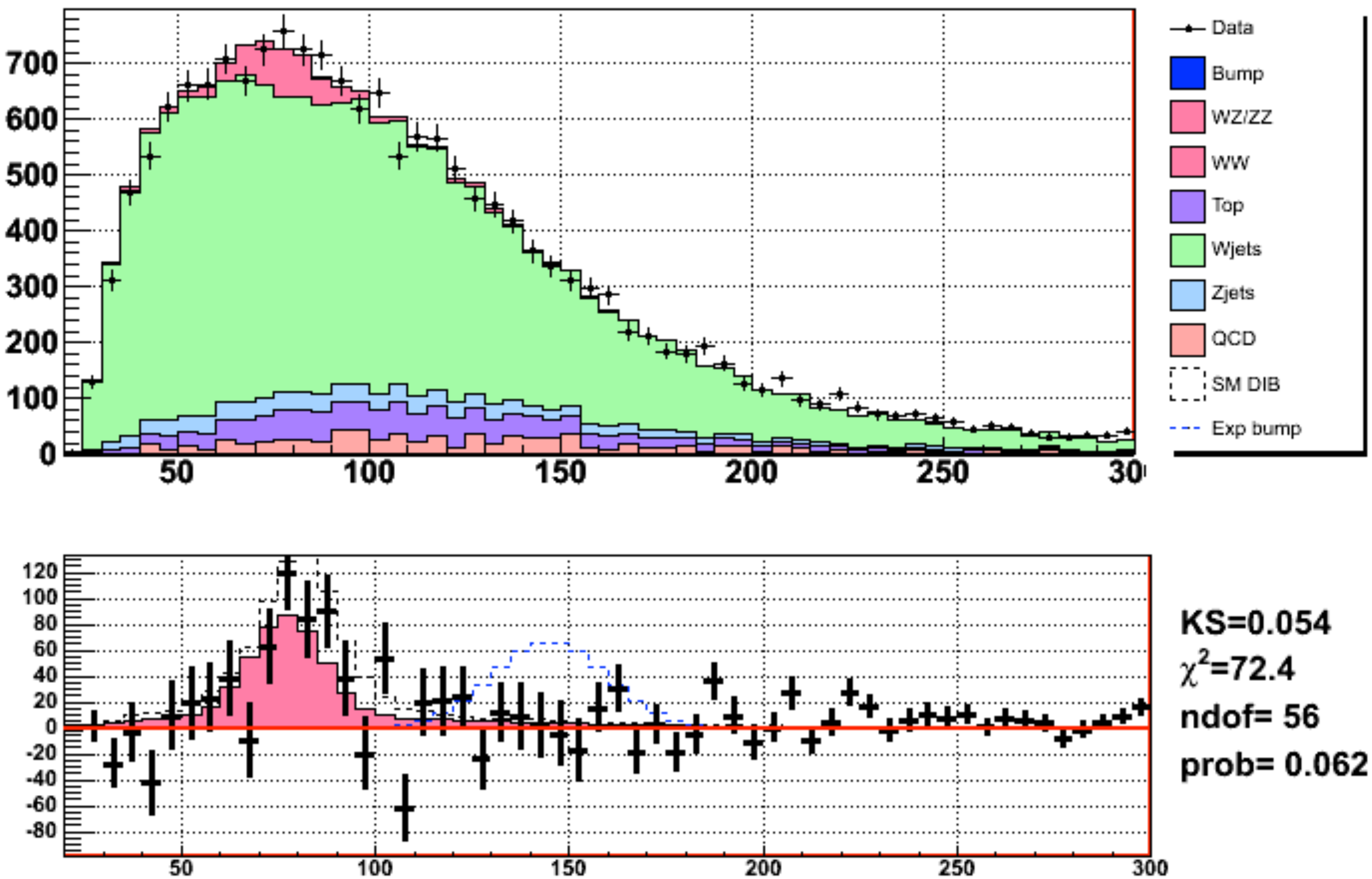
Results



Good agreement between data and SM predictions

Since no resonance was found we establish
$\sigma < 0.9$ pb @ 95% CL

|η|<2 - diboson unconstrained



QCD7 0.000957129 +- 0.998819
TOP 0.569463 +- 0.983292
BNESS 0.380501 +- 0.924596
JES -1.05084 +- 0.431456
ACC 0.116809 +- 1.01775
VJETS1_3UNCONSTRAINED 0.0175867 +- 0.0173152
Q2 0.317986 +- 0.929767
DIBUNCONSTRAINED -0.24457 +- 0.17328
BUMPUNCONSTRAINED -0.999999 +- 0.219306
QCD1 -0.441937 +- 0.707646

1. Two charged leptons + two jets

• Z+jets as dominating contributions

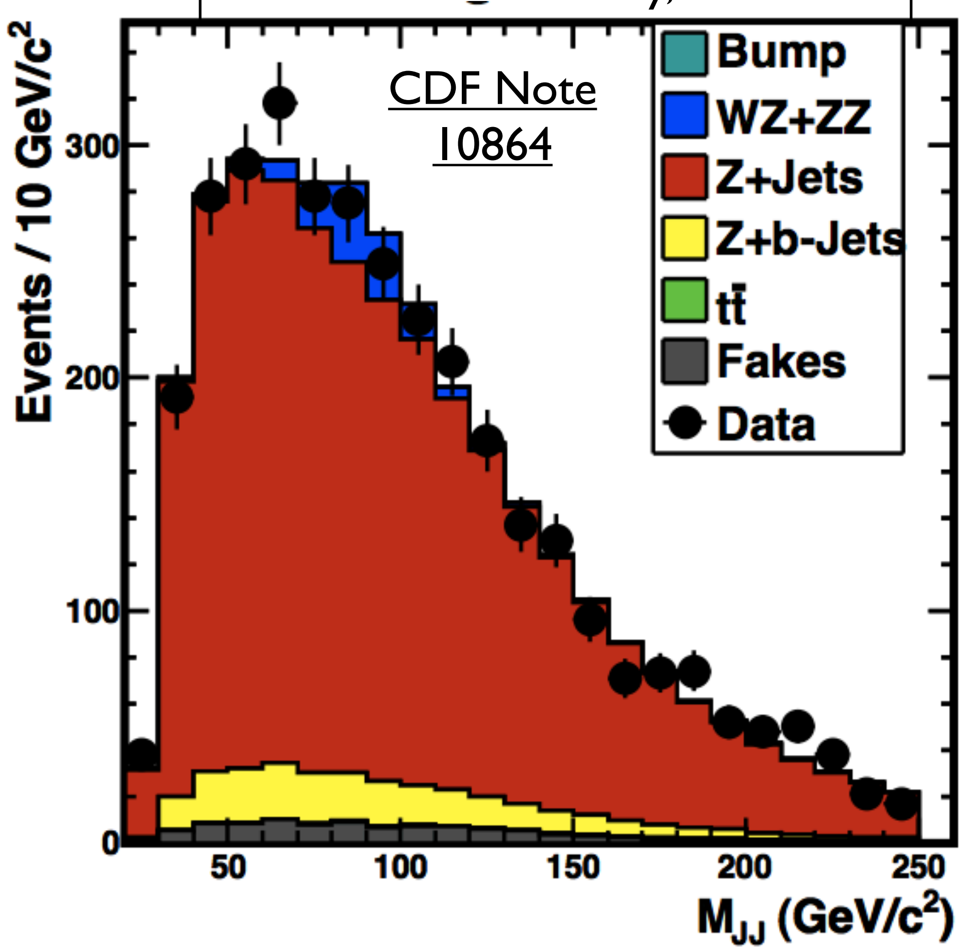
Selection

- =2 charged leptons with P_T >20 GeV/c
- 76<(M(lep1,lep2)/GeV/c2)<106
- $\not{E}_T$<20 GeV
- =2 jets with E_T >25 GeV
  - ΔR(jet1,jet2)>0.7

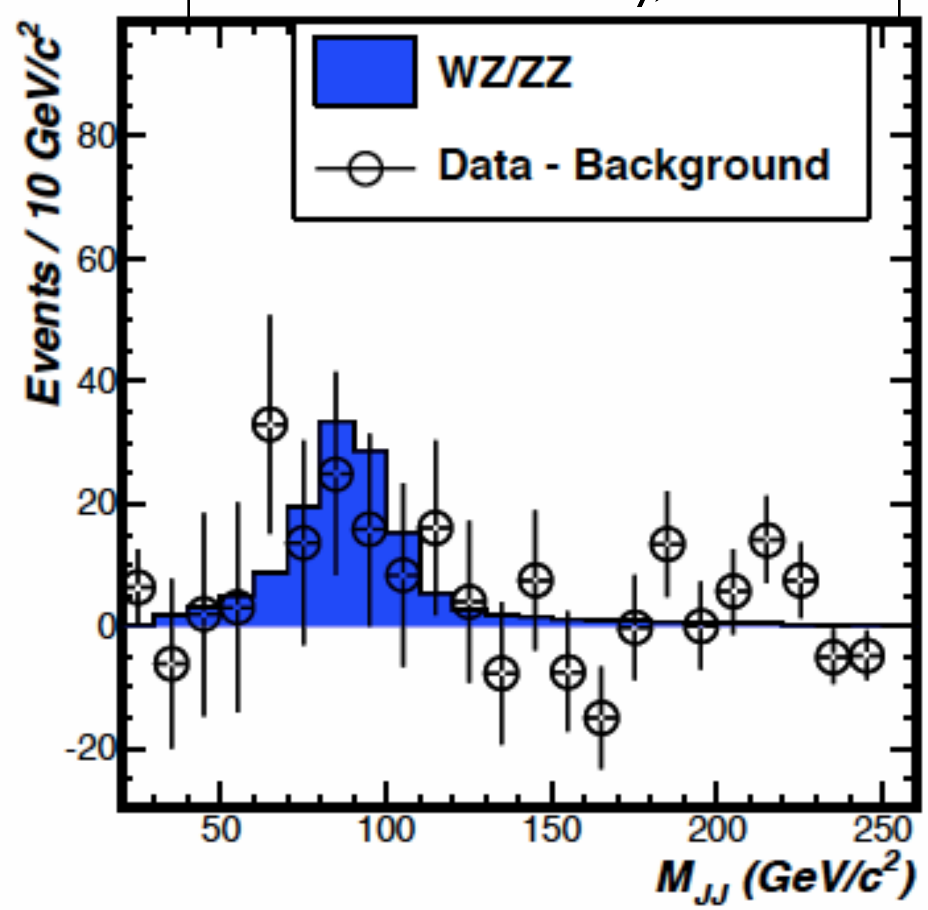
Summary of the aforementioned improvements: ***new-JES***

• new-JES is used as in W+2jets analysis
• different model for the small multi-jet background

CDF Run II Preliminary, L = 8.9 fb^{-1}



CDF Run II Preliminary, L = 8.9 fb^{-1}



1. Two charged leptons + two jets

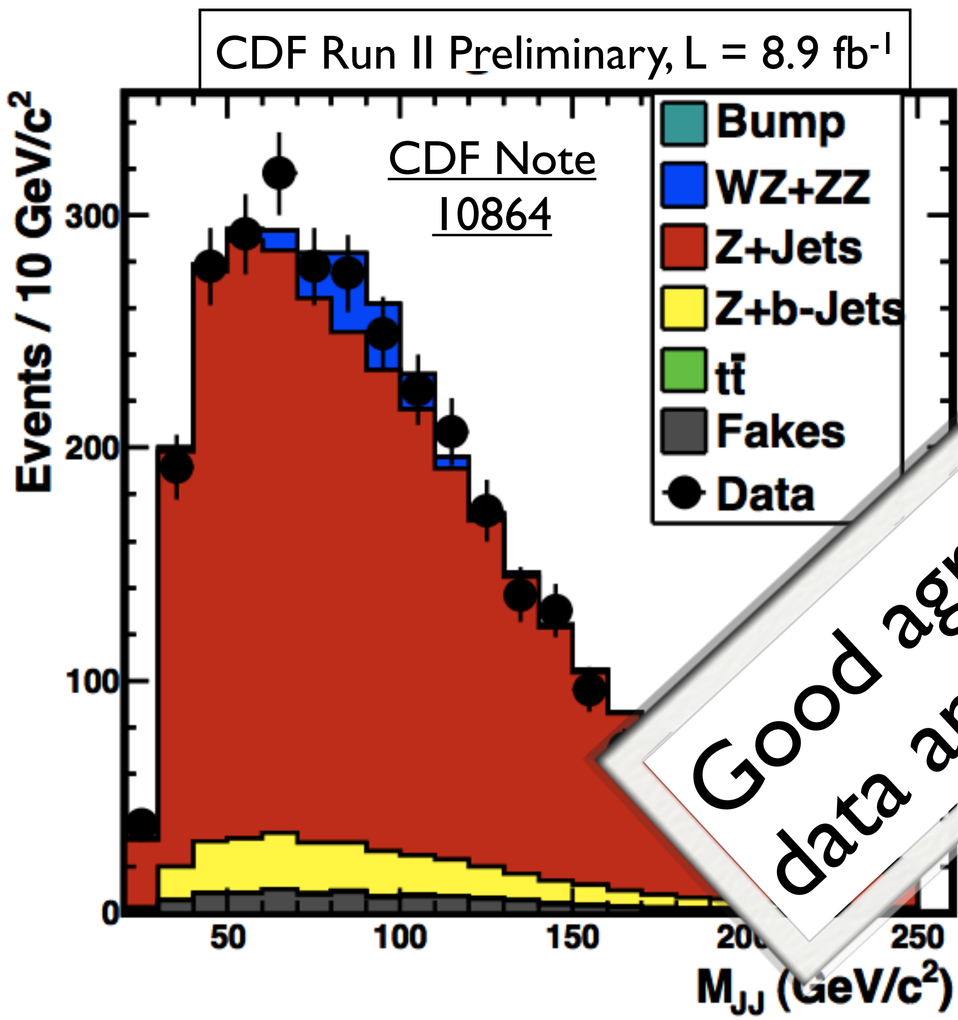
- Z+jets as dominating contributions

Selection

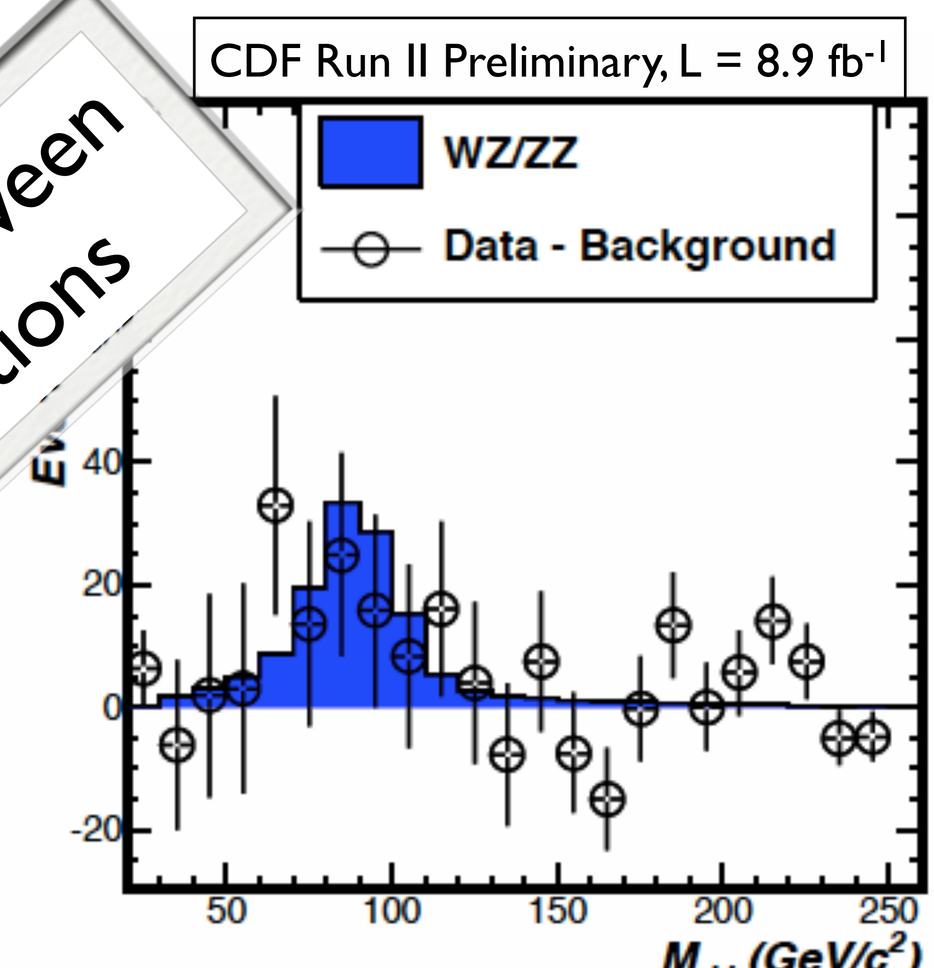
- =2 charged leptons with P_T >20 GeV/c
- 76<(M(lep1,lep2)/GeV/c2)<106
- $\not\!\!E_T$<20 GeV
- =2 jets with E_T >25 GeV
  - ΔR(jet1,jet2)>0.7

Summary of the aforementioned improvements: ***new-JES***

- new-JES is used as in W+2jets analysis
- different model for the small multi-jet background



Good agreement between data and SM predictions



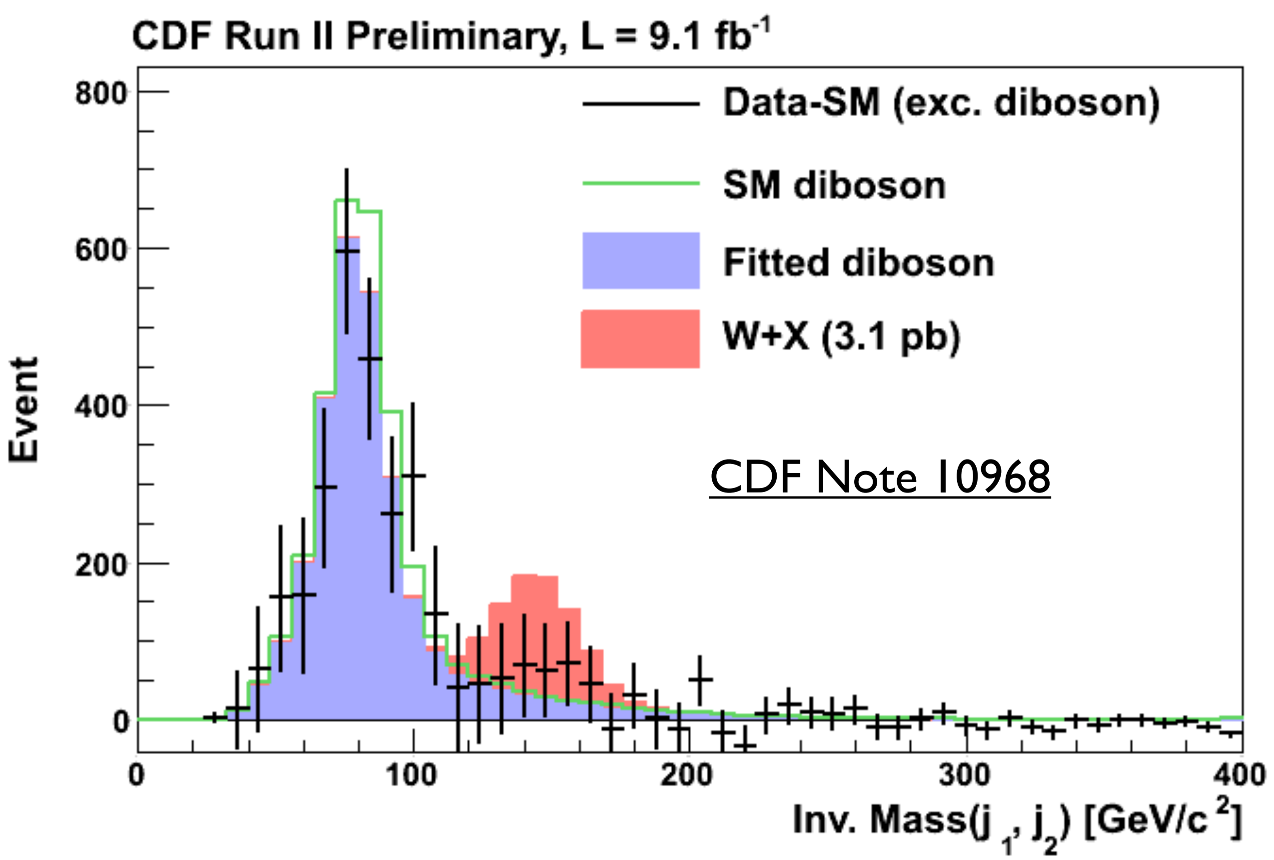
2. Large $\not{E}_T$ + two jets

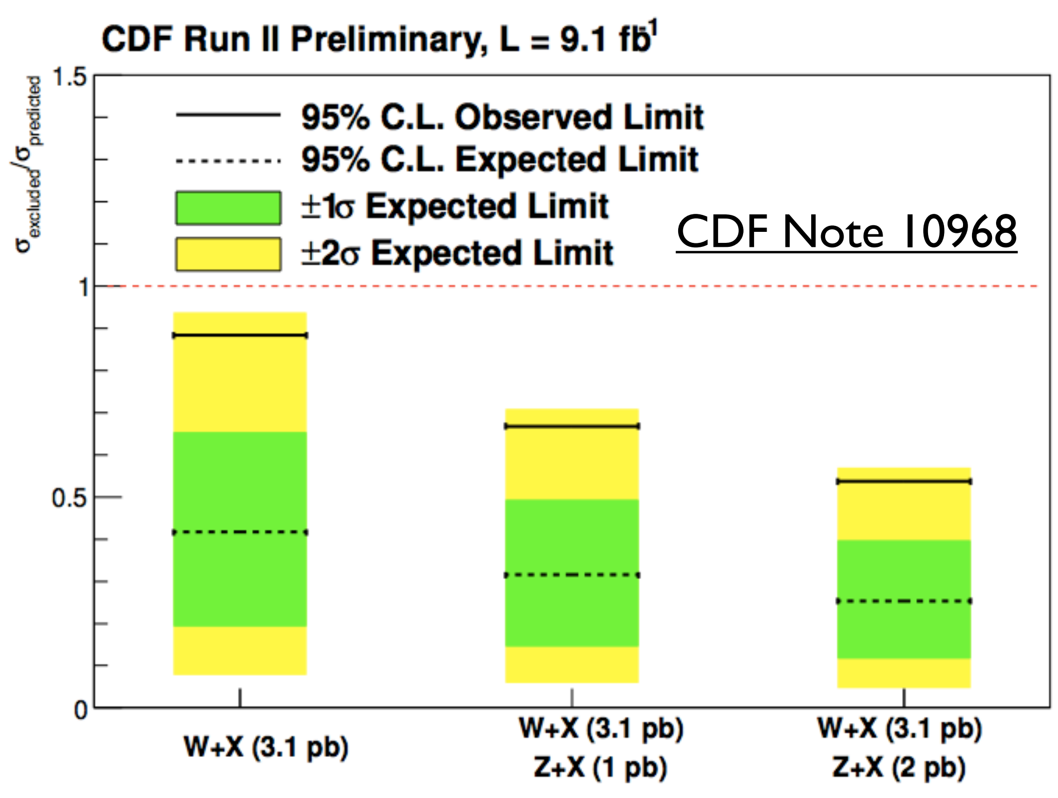
Selection

- no identified lepton
- MET>50 GeV
- =2, (3) jets with E_T >35, 25, (15) GeV
  - $\Delta R(jet1,jet2)>1$, $|\eta_{j1\ or\ j2}|<0.9$

Summary of the aforementioned improvements: **none**

- No Q/G JES
  - lower gluon contamination due to the higher jet energies
- No QCD fix
  - different trigger exploited and no lepton to be faked





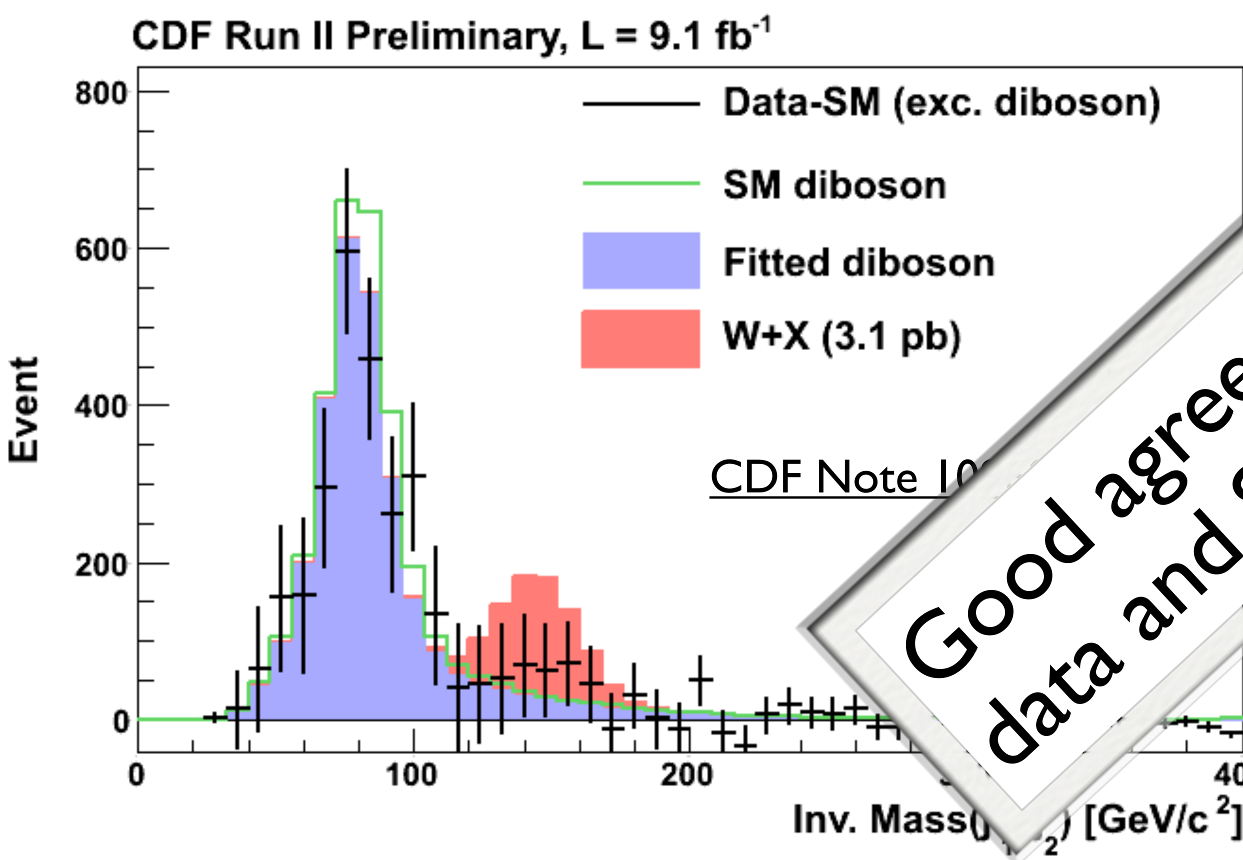
2. Large $\not{E}_T$ + two jets

Selection

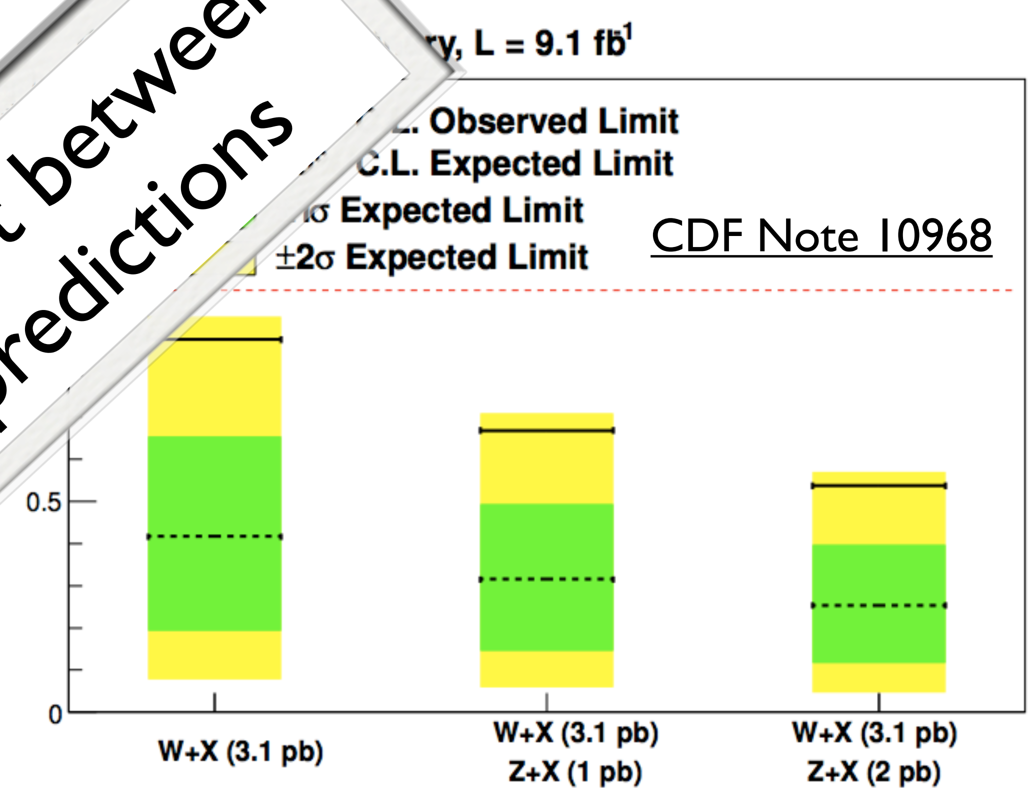
- no identified lepton
- MET>50 GeV
- =2, (3) jets with E_T >35, 25, (15) GeV
  - ΔR(jet1,jet2)>1, $|\eta_{j1 \text{ or } j2}|$<0.9

Summary of the aforementioned improvements: **none**

- No Q/G JES
  - lower gluon contamination due to the higher jet energies
- No QCD fix
  - different trigger exploited and no lepton to be faked



Good agreement between data and SM predictions



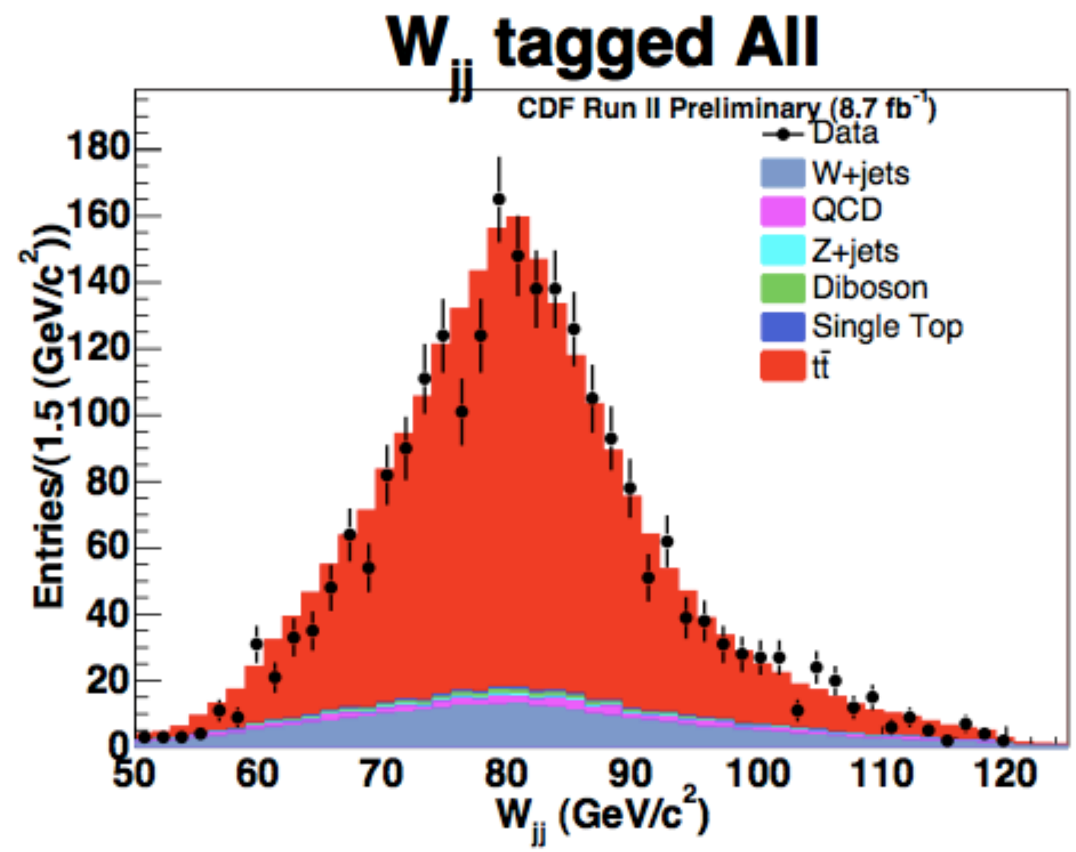
CDF Note 10968

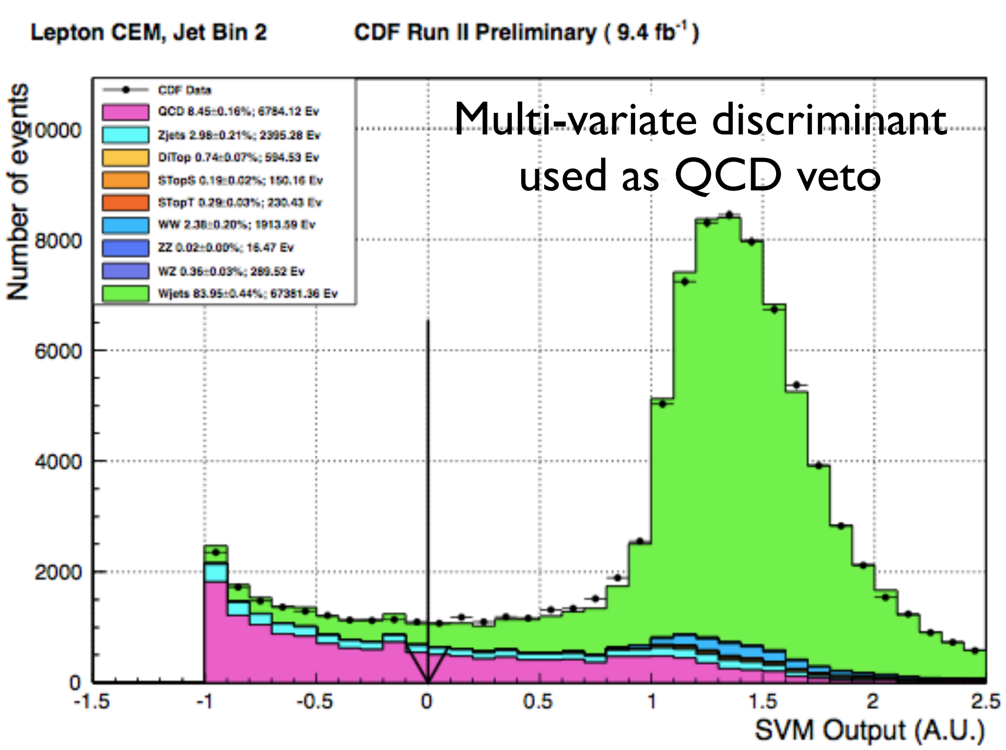
For a mixture of W+X (3.1 pb) and Z+X (1 pb) σ<2.1 pb @ 95% CL

Effect of the changes on main analyses @CDF

1. Top-pairs:

- Effect of the quark/gluon-JES was checked - none
  - Top-pair signal extracted from ~gluon-free samples
- Effect QCD-model fix: negligible
  - QCD/Data < 5%





2. Higgs:

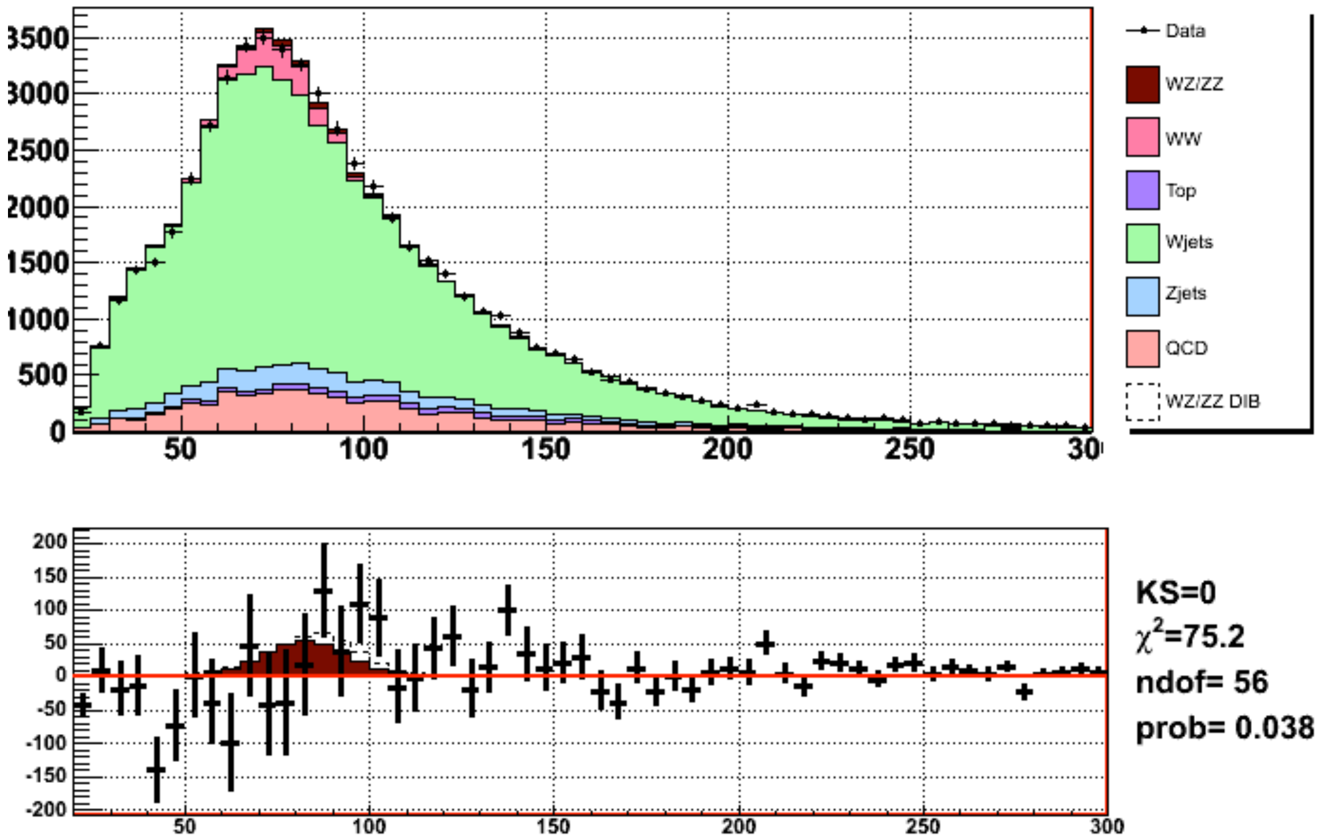
- Quark/gluon-JES already included
- Effect QCD-model fix: negligible
  - Applies only to one out of 3 main analyses
  - Was already partially included
  - QCD/Data ~ 2% thanks to a tight QCD veto

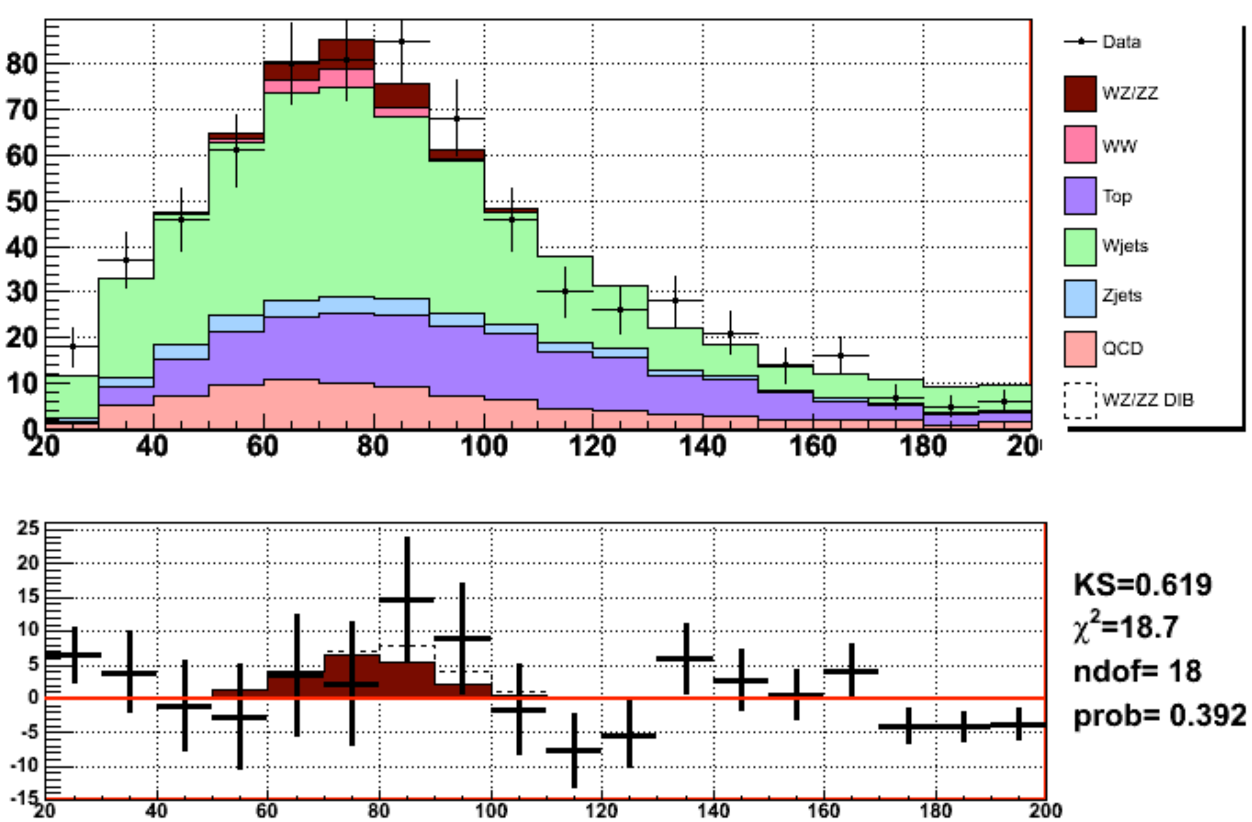
Effect of the changes on main analyses @CDF

3. QCD:

- cross-section analyses use R=0.7 cone-MIDPOINT or antiKT jets
  - those algorithms are less sensitive to soft radiation
  - Data-MC discrepancy even for JETCLU R=0.7 cone jets is within CDF JES uncertainty

Mj1j2 fit





Parameter	Fit value (in units of σ or %)
TOP	0.95 ± 0.97
BNESS	0.20 ± 0.37
JES	-1.11 ± 0.35
Q2	-1.52 ± 0.56
WW	-1.08 ± 0.97
Acceptance	-1.11 ± 0.95
Signal	-0.07 ± 0.67
VJETSTag2j	-0.06 ± 0.08
VJETSNotag2j	0.02 ± 0.01
QCDTCETag2j	0.06 ± 0.94
QCDTCENotag2j	-0.26 ± 0.39
QCDCMUPCMXTag2j	0.02 ± 1.00
QCDCMUPCMXNotag2j	-0.09 ± 0.99
QCDPHXTag2j	0.01 ± 0.97
QCDPHXNotag2j	-0.50 ± 0.25
QCDEMCTag2j	-0.02 ± 1.00
QCDEMCNotag2j	-0.02 ± 0.98