Jterm IV

Measurement of the Forward-Backward Asymmetry in Z->mumu Events in CMS

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Outline

- The forward-backward asymmetry
- Dilution effect from mistag
- Final State Radiation
- Background sources
- PDF Uncertainty
- Afb after all corrections

Forward-Backward Asymmetry definition

• The forward-backward asymmetry in p + p → ɣ*/Z → μμ events arises from the parton level process q + qbar → ɣ*/Z → μμ

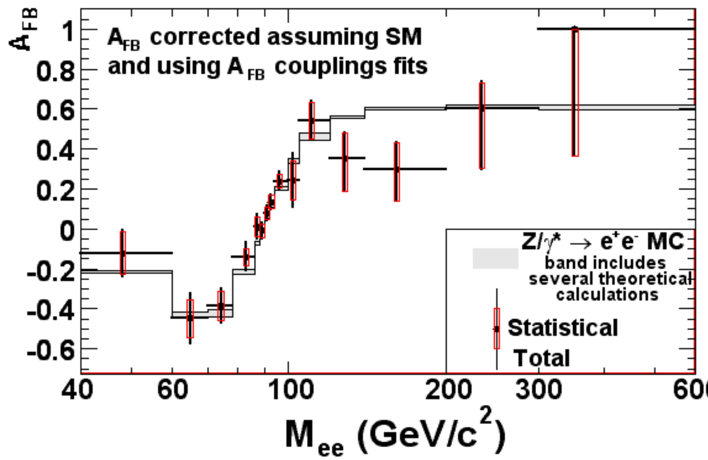
• The presence of both vector and axial-vector coupling of the quarks and leptons to the Z boson gives rise to an asymmetry in the **polar emission of muons**.

• At the Tevatron, Afb is measured as a function of the invariant mass of the dilepton pair

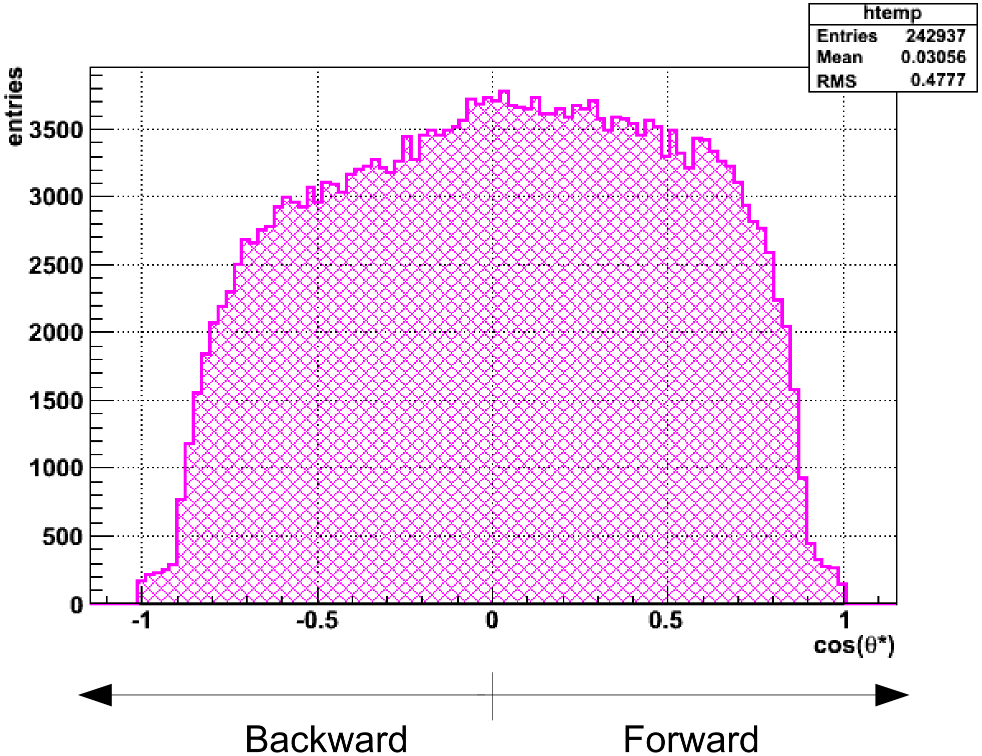
• For mass above 110 GeV, the asymmetry is almost constant(≈ 0.6)

• Around the Z mass peak, Afb is dominated by the couplings of the Z boson and has very small value.

CDF (p+pbar)



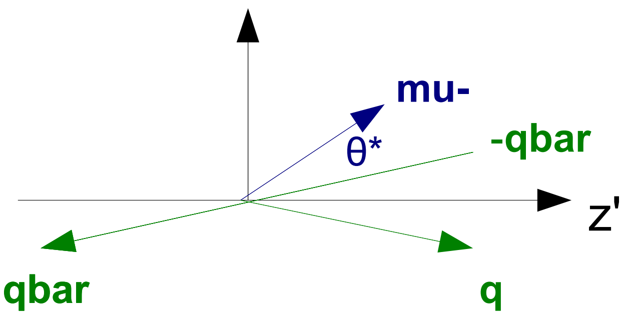
The Measurement



- **Forward** events (cosϴ*>0)
- **Backward** events (cosϴ*<0)

For each mass bin, we calculate the asymmetry given by

$$A_{fb} = \frac{(N_f - N_b)}{(N_f + N_b)}$$



•Collins-Soper frame:

θ* is the angle between the muon momenta and a z' axis that bisects the angle between **q** and **-qbar**.

J.C. Collins and D.E. Soper, Phys. Rev. D 16, 2219 (1977)

Samples

Data Sample	Events	Xsection(pb)	Filter	Lumi (pb^-1)
1)Zmumu_M20	1,296,192	1944	1	666.8
2)InclusiveMuPt15	6,309,808	509,100,000	0.000239	51.8
3)W+jets	10,304,227	40,000	-	257.6
4)tt+jets	1,028,322	317	-	3,243

1) Zmumu_M20/Summer08_IDEAL_V11_redigi_v1/GEN-SIM-RECO
2) InclusiveMuPt15/Summer08_IDEAL_V11_redigi_v1/GEN-SIM-RECO
3) WJets-madgraph/Fall08_IDEAL_V9_v1/GEN-SIM-RECO
4) TTJets-madgraph/Fall08_IDEAL_V9_v2/GEN-SIM-RECO

*Lumi will be scaled to 200 pb^-1

HLT and Offline Selection

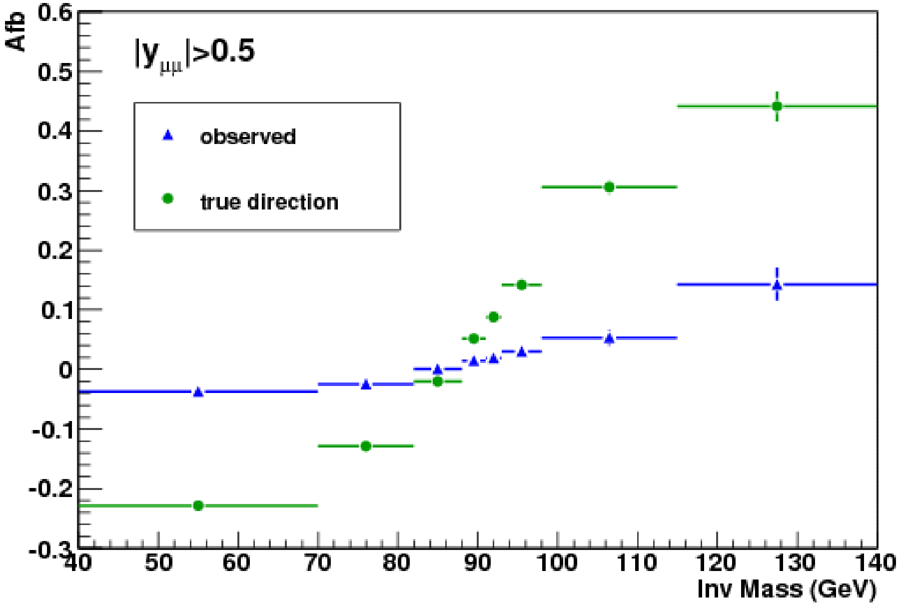
- HLT_Mu15 (single muon trigger, unprescaled)
- Find the muon that matches the Trigger Object and
    - GlobalMuon
    - $|\eta| < 2.1$
    - pT > 20 GeV
    - Iso < 3 GeV

    - Find the second muon that
        - GlobalMuon
        - $|\eta| < 2.1$
        - pT > 20 GeV
        - Iso < 3 GeV
        - charge = - charge (mu1)

Total efficiency: ~20%

F/B Asymmetry at LHC

In order to measure this F/B Asymmetry, we need the information about the **direction of the quark**, which is not known in proton-proton experiments. This lack of information leads to a **dilution** in the Asymmetry.

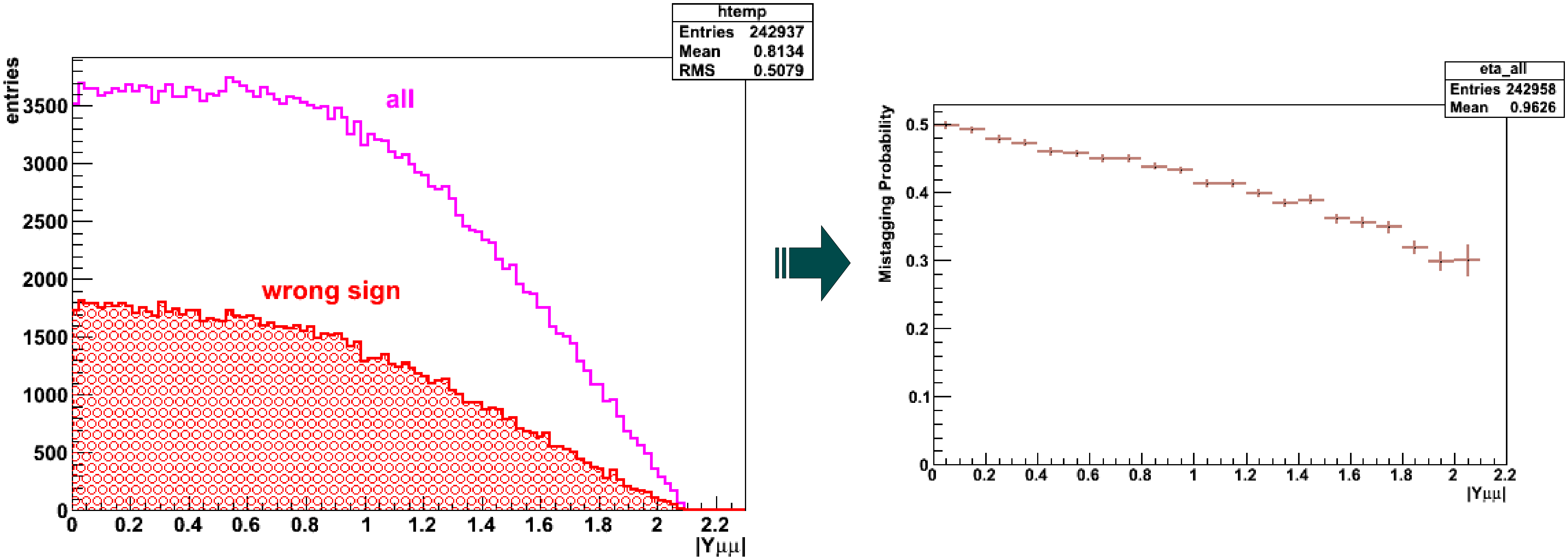


Mistagging

• The Dimuon system is **assumed** to be in the quark direction (valence quark is likely to carry more momenta). Mistagging happens when in fact in the anti-quark one.

• Mistagging probability depends on dimuon system rapidity and mass.

• How often?



R. Cousins, J. Mumford, V. Valuev, CMS NOTE 2005/022

How to correct mistag effect using data (and PDF)?

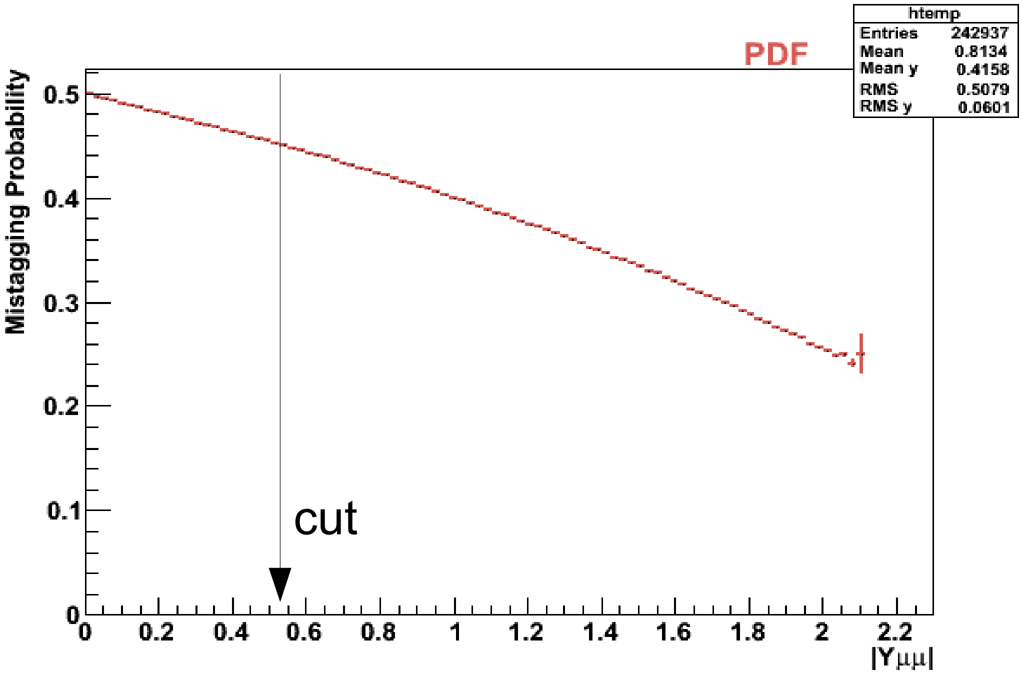
- Event-by-event correction
- For each event we obtain the dimuon η
- Calculate x1 = Q . exp [η]/√s
- Calculate x2 = Q . exp [-η]/√s

Case 1) η > 0 => x1 > x2
Case 2) η < 0 => x2 > x1

MistProb(case1) =

$$\frac{q(x2).qbar(x1).q^2}{q(x1).qbar(x2).q^2+(x2).qbar(x1).q^2}$$

(summed over all flavors)



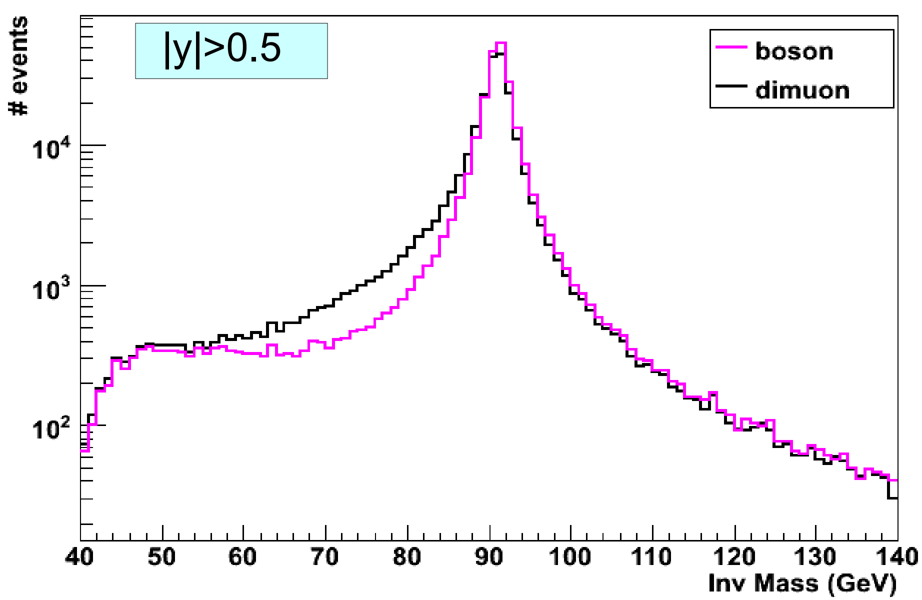
observed asymmetry
A' ~ (1-2*mistProb)*A

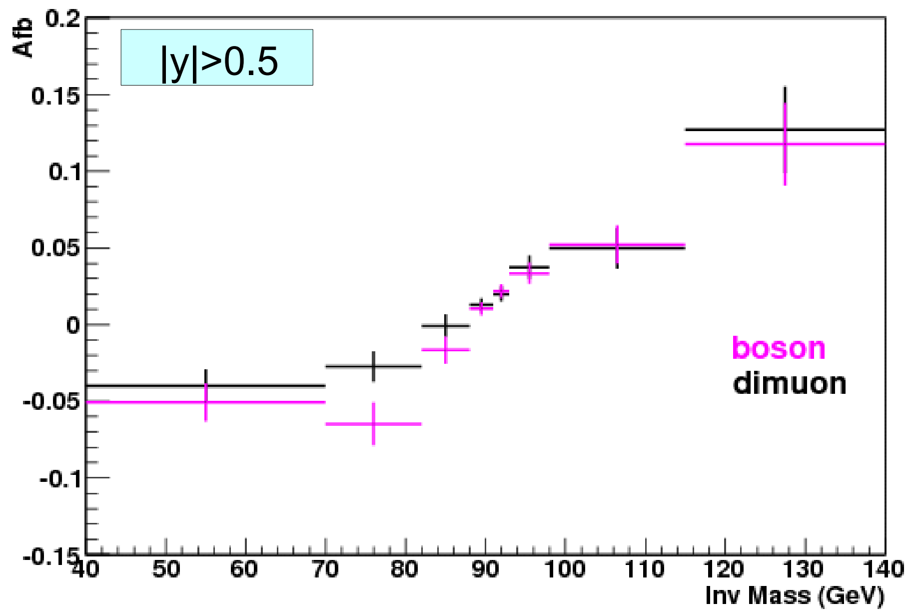
(MistProb = 0.5 => no asymmetry information)

Final State Radiation effect

In order to understand the effect of the FSR in this analysis, we show the invariant mass distribution for all the events that pass the event selection and the further cut on the dimuon system rapidity.

The figure shows two different levels. One is the **boson** invariant mass (obtained from MC) and the other is the **dimuon** invariant mass.The difference occurs at the mass region up to the Z mass peak because the muons from the Z radiate down to lower dimuon mass.





Unfold Method

What is the probability that one event measured in mass bin i was generated in mass bin j?

1. Get the reco mass bin
2. Check if the event had $\cos(\theta^*) > 0$ (forward)
3. For the same event, get the gen mass bin
4. Check if $\cos(\theta^*) > 0$ (forward) , generator level
5. Construct 4 matrices, Mff, Mfb, Mbb, Mbf

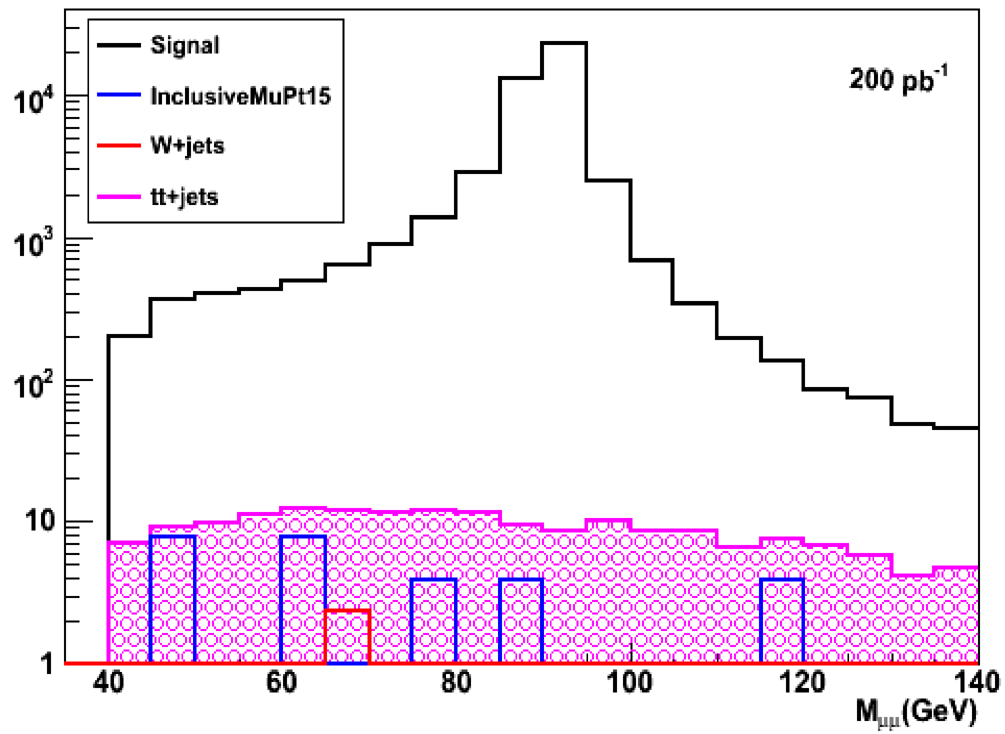
Mfb (i,j) = Probability that an event reconstructed as **f**orward in bin **j** was generated as **b**ackward in bin **i**.

N'f(i) = ∑ [Mff(i,j) * Nf_reco(j) + Mbf(i,j) * Nb_reco(j)]

N'b(i) = ∑ [Mbb(i,j) * Nb_reco(j) + Mfb(i,j) * Nf_reco(j)]

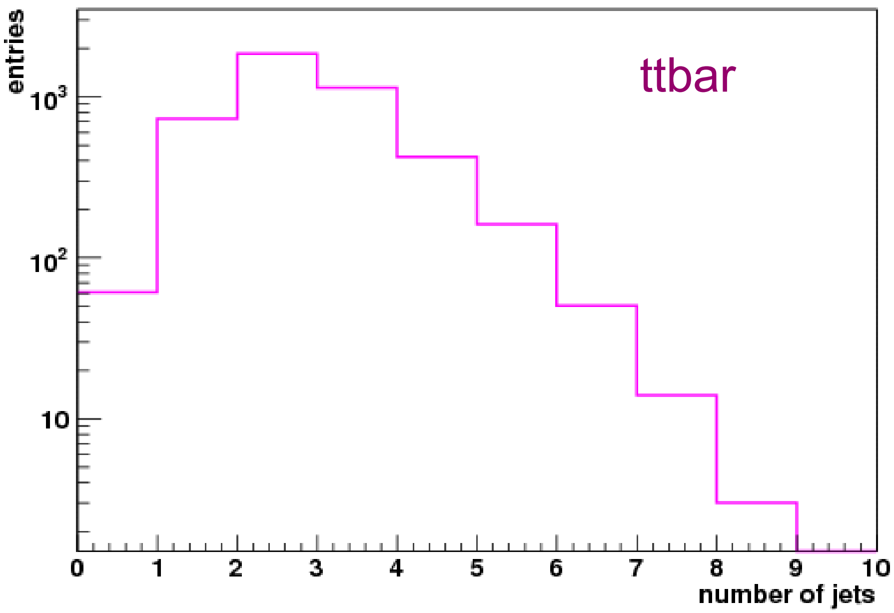
arXiv:0804.3220v2 [hep-ex]

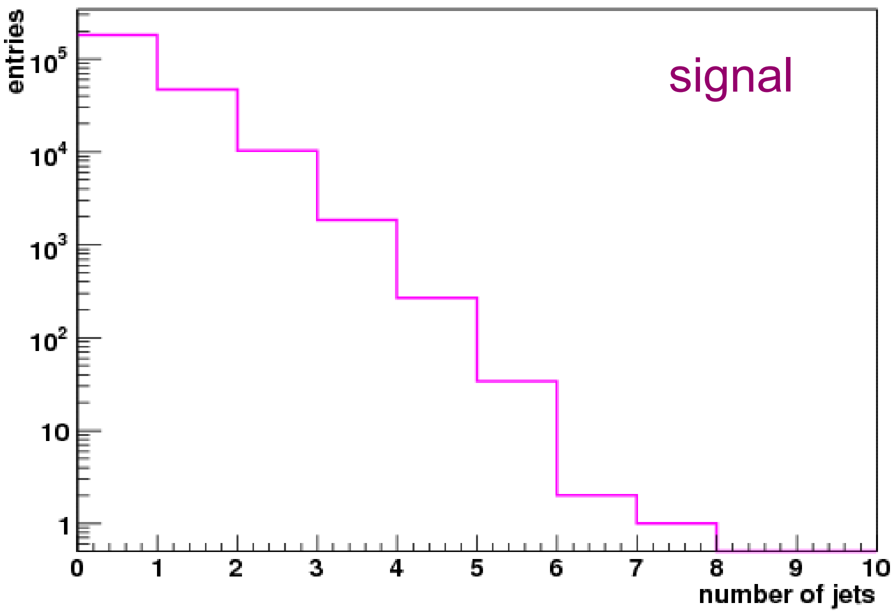
Background sources



- After event selection
- Cut on muon system rapidity (|η| > 0.5 – mistag probability) already applied
- Overall very small

Minimizing background

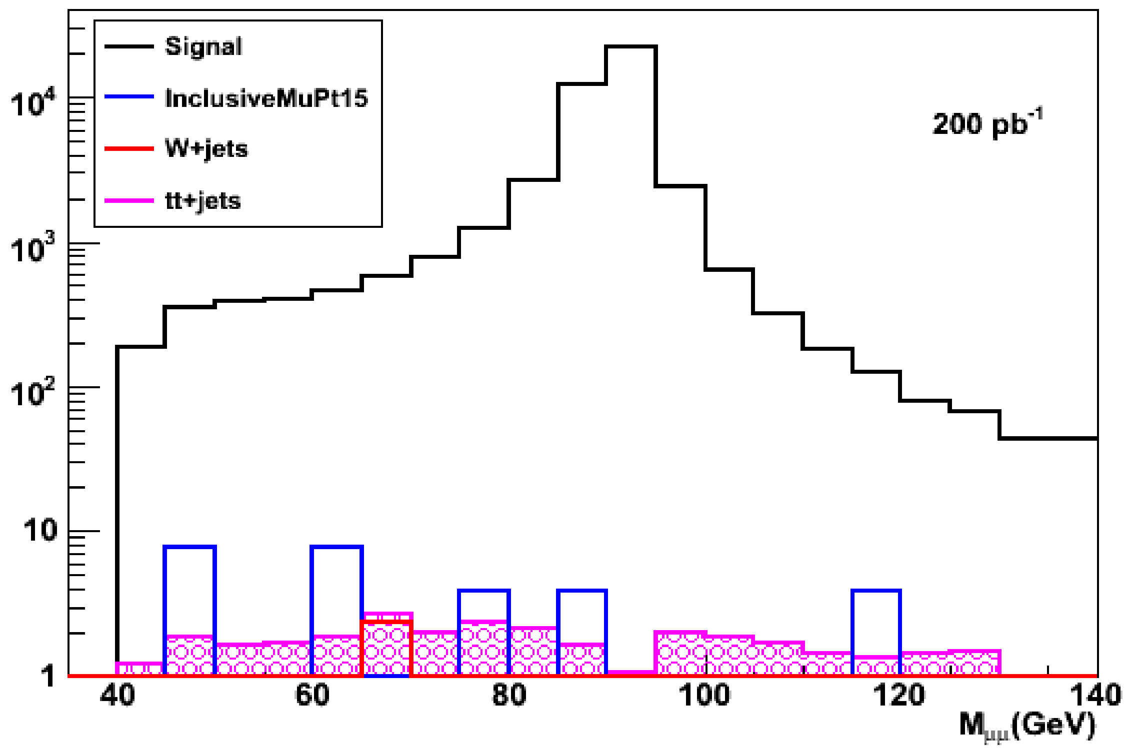




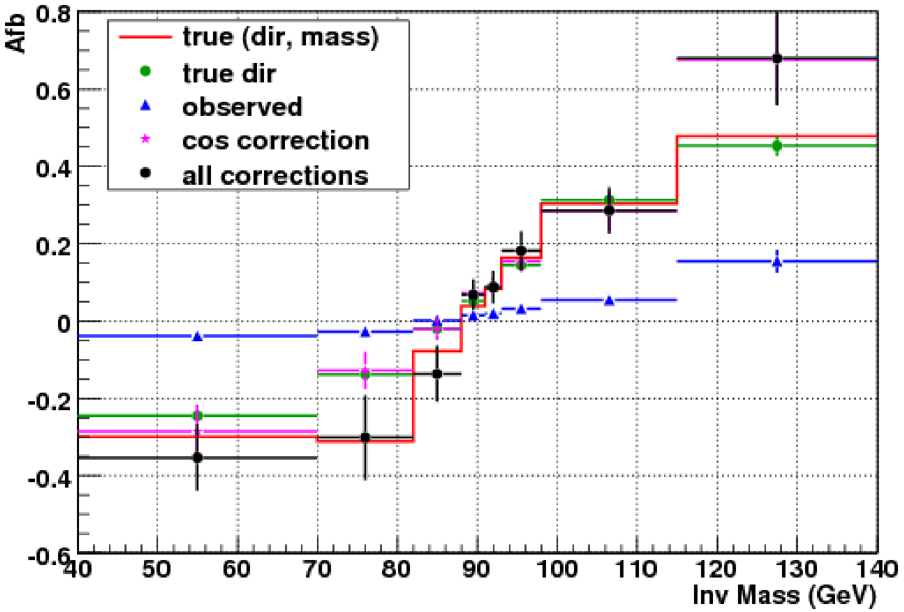
	# jets < 2	# jets < 3
Zmumu	94,8%	99,1%
tt+jets	17,9%	59,6%

- Choosing the cut njets < 2
- Jets are corrected and have pT > 30 GeV

Effect of cutting on number of jets (njets < 2)



F/B Asymmetry after all corrections



PDF Uncertainty and Reweighting Method

• PDF(x,f,Q): Probability to find a parton of flavor f, carrying a fraction of proton momenta x, at a given scale Q

• PDFs are essential inputs to make theoretical predictions at hadron colliders

• CTEQ group provides information of best fit PDF and a set of error PDFs

• The Brute Force Method, one needs to
  - generate M=2N+1 samples
  - calculate observable X of interest (for each sample)
  - use Master Formula and 2N error PDFs to obtain the uncertainty

• Instead of generating 2N+1 samples, one can use only one sample and, for every single event, calculate 2N+1 weights (Reweighting Method).

• The weights depend on the quarks flavors and momenta

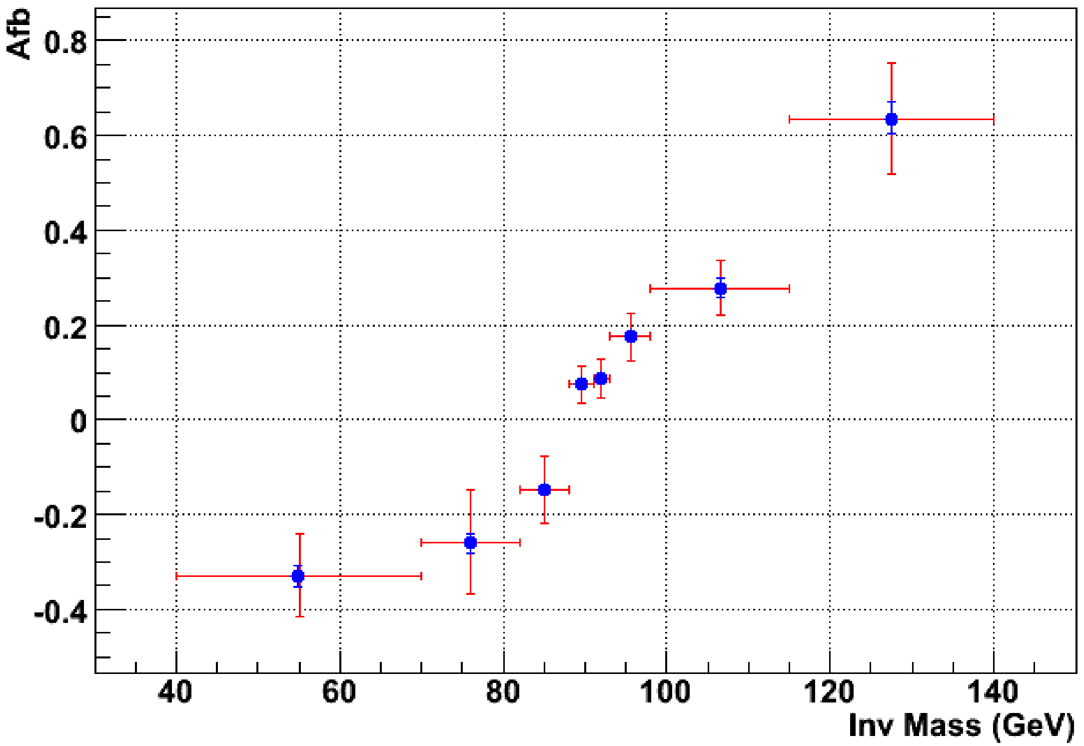
• Compute for each event a set of 2N weights (+/- contributions)

• PDF set used: CTEQ6 (41 parameters; N=20)

• Again use the Master Formula to obtain the uncertainty

References:
• https://twiki.cern.ch/twiki/bin/view/CMS/PdfUncertaintiesForHWW
• AN2009_048

PDF impact on the F/B asymmetry analysis?



Statistic (with some systematic) error
PDF error

Conclusions

• We demonstrated that the true asymmetry can be unfolded using mistag calculations

The results obtained after all corrections (mistag, FSR and detector resolution)
are in agreement with the MC truth

• Mistagging dilutes asymmetry

• Small background contribution

• PDF impact on F/B Asymmetry ~ 6% (CTEQ6)

Backup slides

Efficiencies for Signal Sample

	cut	# events	Rel. efficiency
	generated	1,186,190	-
mu1	Muon reco	937,995	0.79
	|y| < 2.1	860,712	0.92
	pT > 20 GeV	518,711	0.60
	Trigger fired	489,043	0.94
	GlobalMuon, iso	470,028	0.96
mu2	Muon reco	354,784	0.75
	|y| < 2.1	310,777	0.88
	pT > 20 GeV	247,591	0.80
	GlobalMuon	233,513	0.94
	Isolation	220,278	0.94
	charge1 = -charge2	220,273	~100%

Total efficiency: ~20%