CDF-DØ Alpgen Meeting

FNAL, April 5, 2007

NLO for heavy flavor W+jets

- Stating the problem: goals and past experience
- Differences between matched Alpgen and LO MCFM
- Loosening MCFM parton level cuts to study sensitivity of the k-factors: try to match MCFM and Alpgen
- HF fraction from MCFM
- Studying massive b-quarks effect: prescription
- Wbj at NLO in MCFM: how to handle it?
- We have data: make the measurement!

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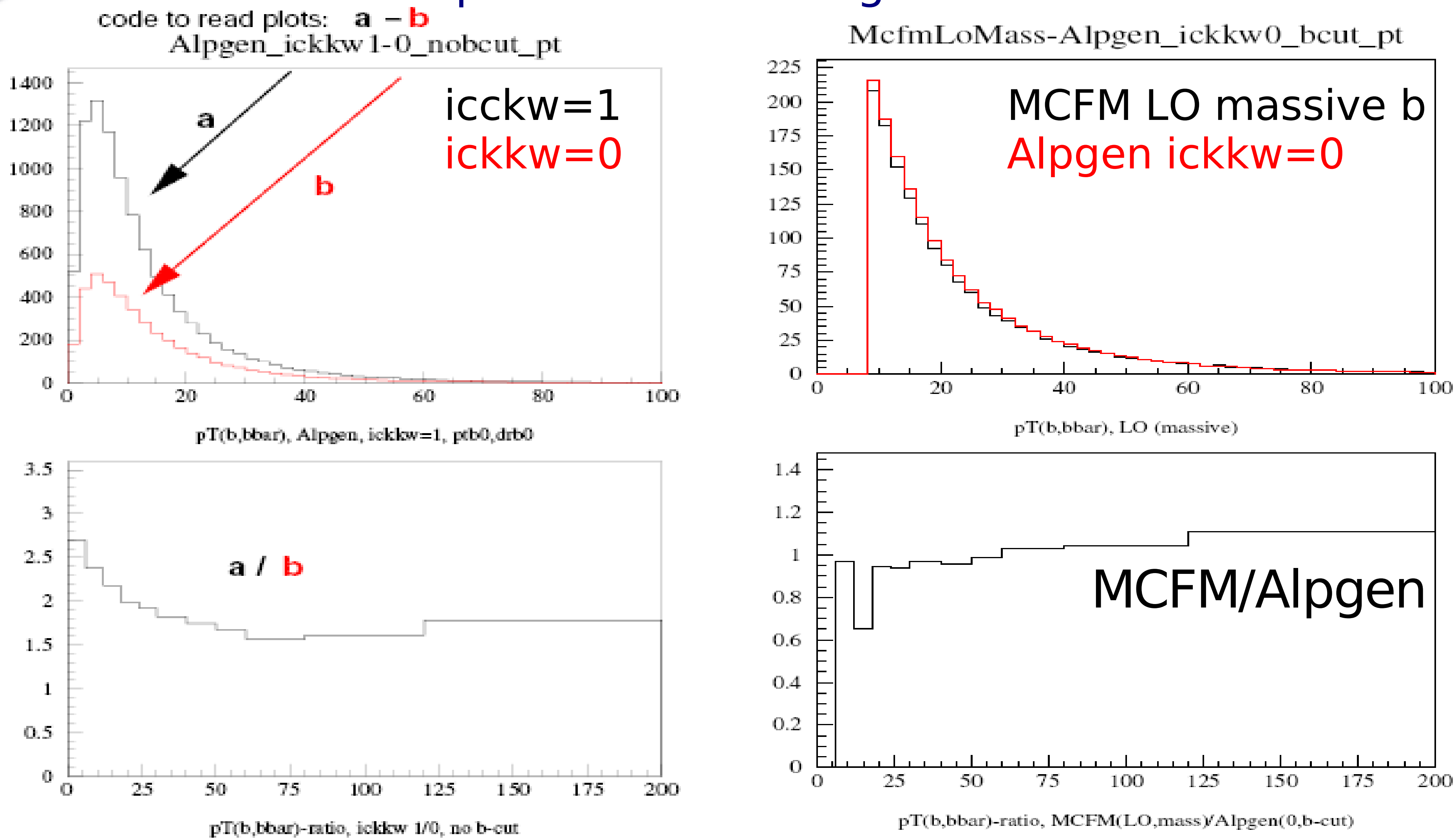
The problem

- We know the NLO cross section changes wrt LO values for Wbb and Wcc, and also for Wjj
- Since we usually normalize all W+jets to data, the problem is not so much the absolute σ(Wbb) or σ(Wjj), but the fraction of Wbb (and Wcc) in W+jets: the HF ratio
- Our Alpgen samples have LO cs values and massive b's, and they are matched (generated with no parton cut on b pT)
- MCFM gives NLO with massless b's and requires a b pT cut
- In the past, Alpgen was not matched and we could use MCFM with the same Alpgen parton cuts (away from m_b) and got a NLO value for both Wbb and Wjj, and ensured the HF fraction was that NLO ratio.
- But now Alpgen is matched, so what NLO σ should we use, i.e. what is the effect of not using parton cuts in Alpgen? And what is the effect of massive b's?
- We need to know a σ_{NLO}(Wbb)/σ_{NLO}(Wjj) that is applicable to our Alpgen v2.06 samples, and study its limitations

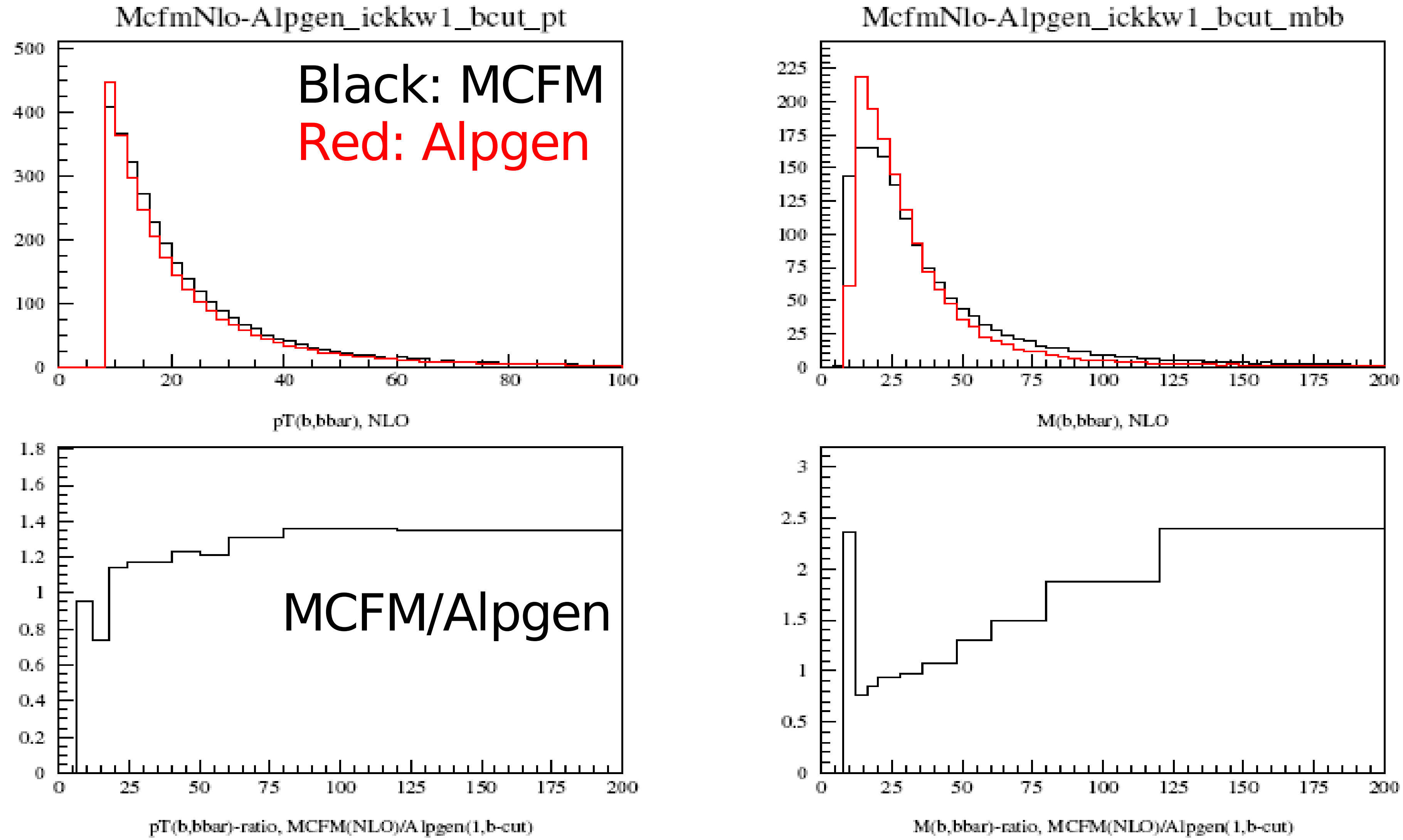
Matched Alpgen issues (T. Nunnemann)

- Alpgen σ(Wbb) much larger (x2) with ickkw=1 than 0 → fixed in v2.1
  - ickkw=1 implements the CKKW prescription for the running of α's in the extra gluon emission processes
- Good agreement in LO MCFM and Alpgen ickkw=0 distributions
- But ickkw=1 is required for matching!



Matched Alpgen issues

- Compare Alpgen v2.06 in DØ production and MCFM (NLO)
- "k-factors" are large and depend on kinematics!

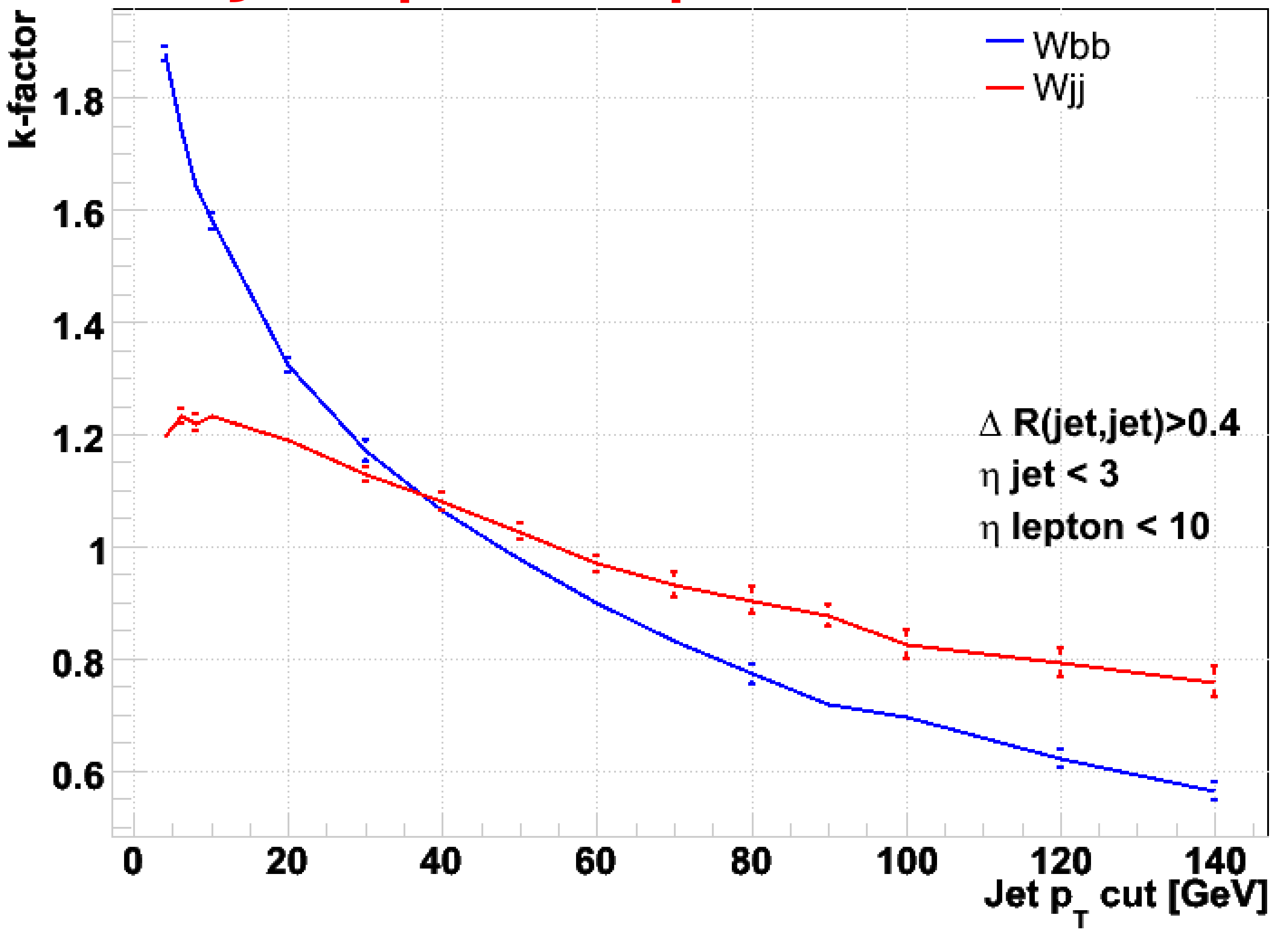


- MCFM (NLO) (closest to the truth) vs. Alpgen (as in production, except b-cut)

Parton cuts dependence

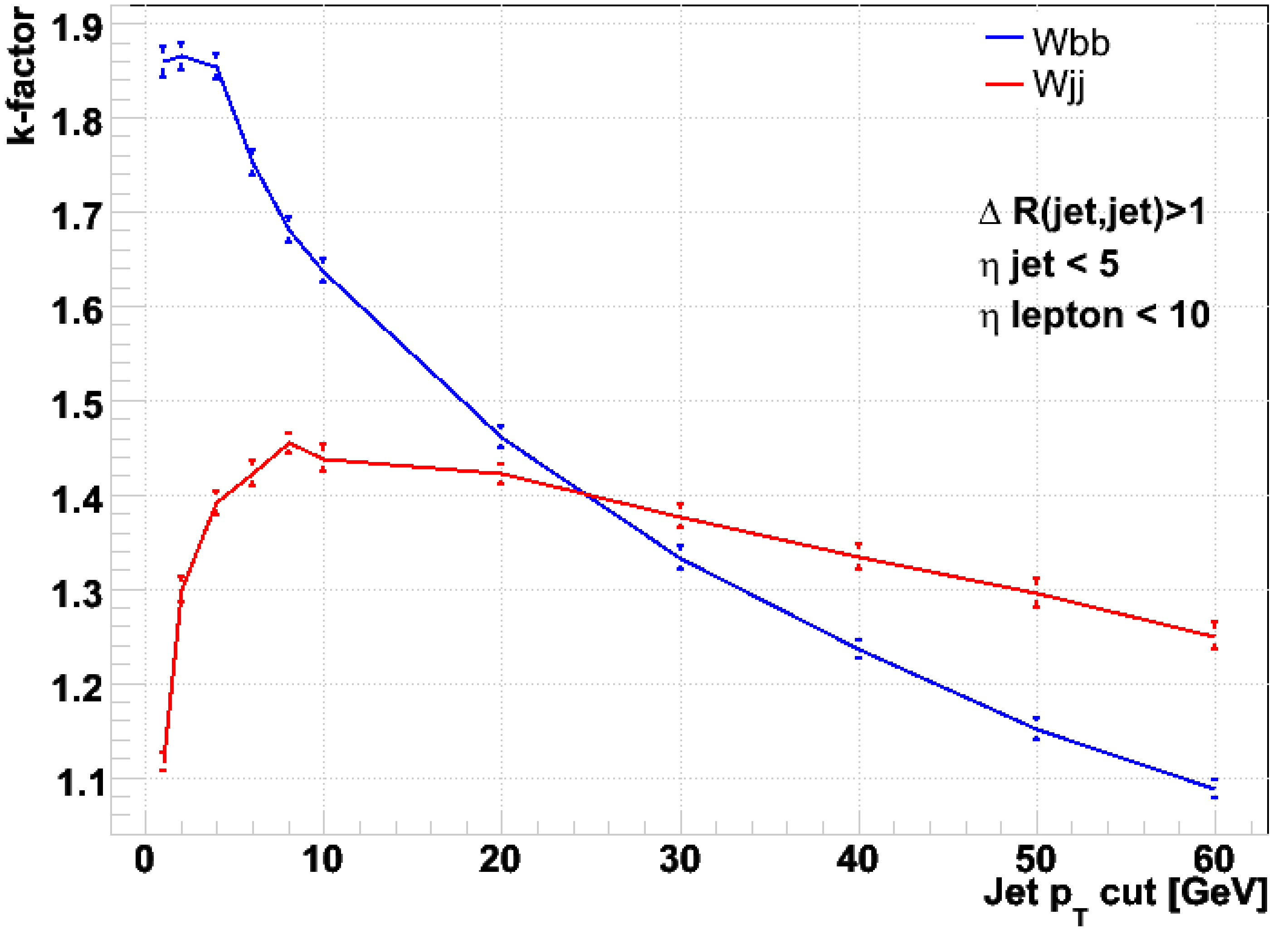
- LO MCFM and LO Alpgen are hard to compare!
  - Default matching settings did not agree with MCFM
- So let's take a look at the old MCFM NLO numbers and see if we can relax the parton level cuts and get something meaningful
- In Alpgen 1.3.3-1 (with no matching), we used:
  - p_T(jet) > 8 GeV, $|\eta$(jet)$|$ < 3.0 and ΔR(jet,jet) > 0.4
  - And then used MCFM with same parton cuts to get NLO
- In Alpgen 2.06 there are no parton cuts, but we use the following cuts for the MLM clustering criteria:
  - p_T(jet) > 8 GeV, ΔR(jet,jet) > 0.4
- What cuts should we use in MCFM to compare to MLM?
- Tables of results can be seen here

Jet pT dependence



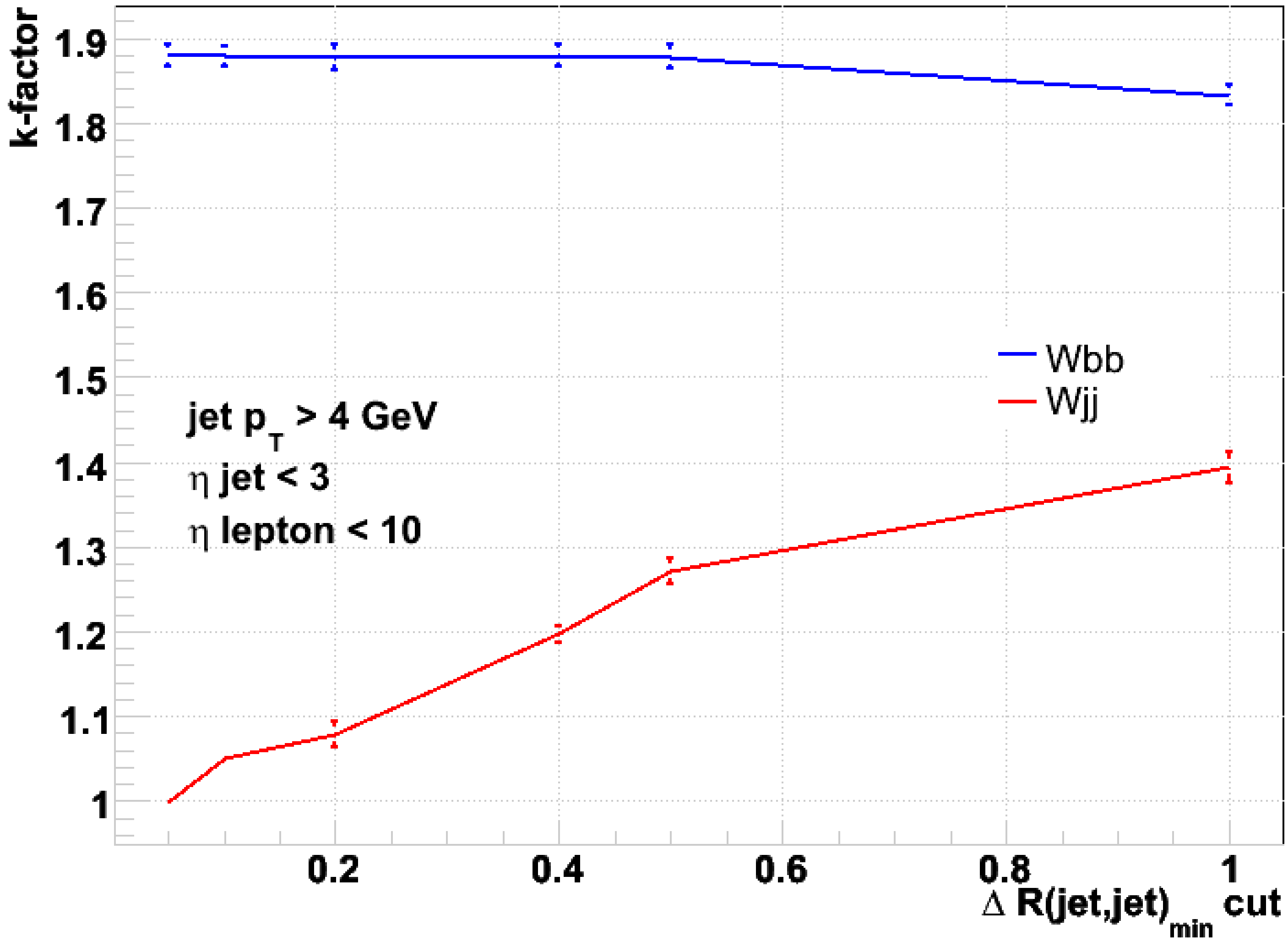
- Pretty large dependence of the Wbb k-factor with jet pT
- We should be making a b jet pT dependent correction
- Although Wbb matched Alpgen with constant scale factor (+acceptance cuts) seems to agree well with data

Jet pT with other cuts and smaller pT



- I'm not sure I understand the difference between this plot and the previous one, based on the different cuts
- Mass effect turn on at pT~5GeV: MCFM always requires pT(b)>4.620 & m(bb)>9.240, to simulate the effect of mass

DeltaR(jet,jet) cut dependence



- Allowing for more jet merging (smaller ΔR(jet,jet) cut) decreases by 20% the Wjj k-factor down to k-factor=1
- Wbb k-factor is unaffected

Summary of cuts dependence

- To summarize what we have seen:
- No lepton η cut dependence: 10 is fine
- No jet η cut dependence: 3 is fine
- Relaxing the jet p_T from 8 to 4 GeV gives:
  - Wbb 1.642 $\rightarrow$ 1.880 (+14%); Wjj 1.220 $\rightarrow$ 1.197 (-2%)
  - Huge jet pT dependence for higher jet pTs
- Wjj k-factor changes with ΔR(jet,jet), Wbb is stable.
  - Going from 0.4 to 0.05: Wjj k-factor 1.2 $\rightarrow$ 1.0 (-17%)
  - Going from 0.4 to 1: Wjj k-factor 1.2 $\rightarrow$ 1.4 (+17%)
- We cannot simply apply our old factors
- We could take the numbers from our loosest operating point: what errors?

What we really want

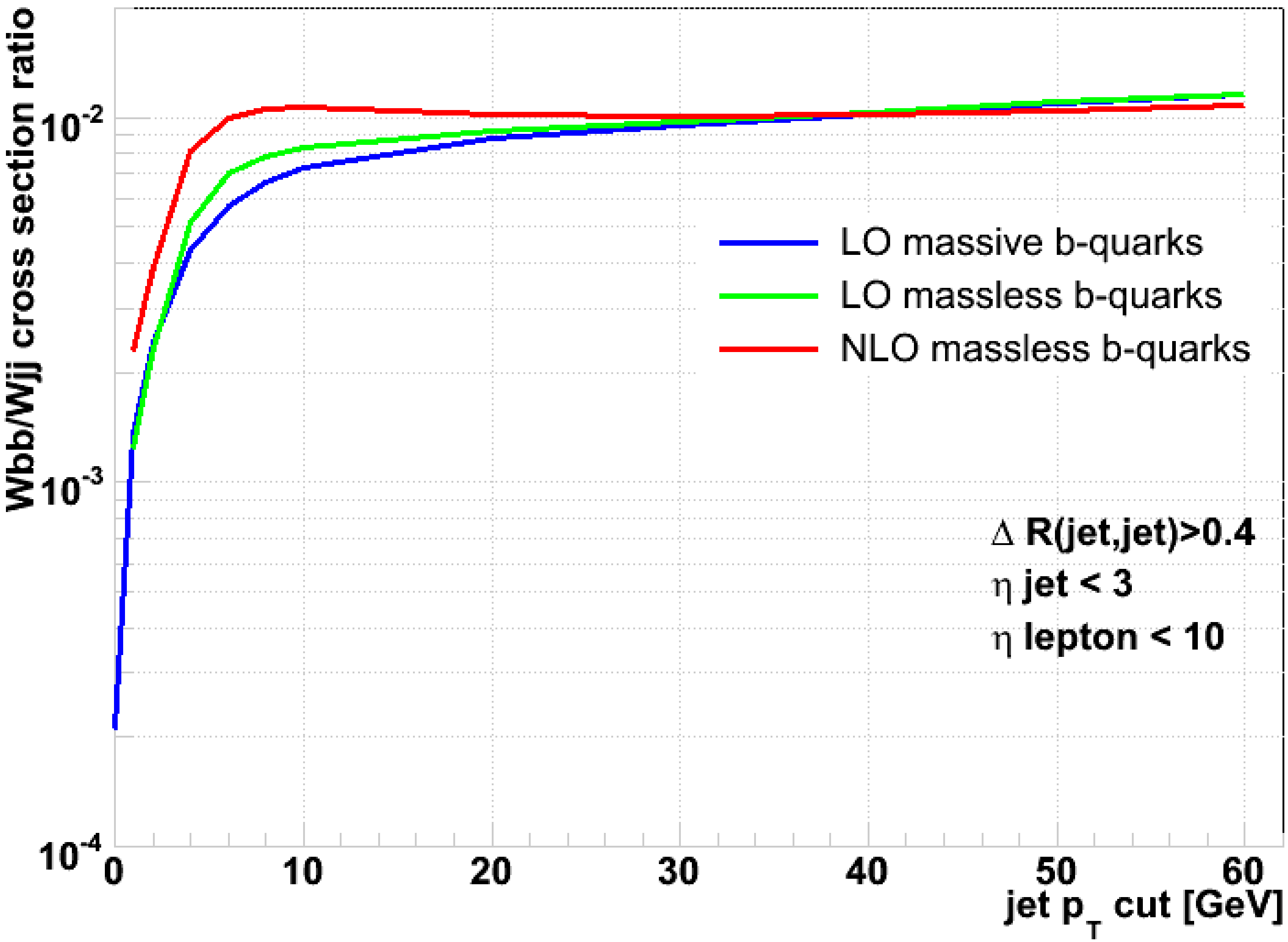
- We really only need σ_{NLO}(Wbb) and σ_{NLO}(Wjj) for a given point
- In other terms, you can calculate how much you need to boost your Wbb contribution over Wjj in Alpgen to account for NLO: HF factor=(Wbb k-factor)/(Wjj k-factor)

Jet pT	Wbb k-factor	Wjj k-factor	HF factor
4	1.880	1.197	1.571
6	1.742	1.233	1.413
8	1.642	1.220	1.346
10	1.580	1.232	1.282

- Ideally, we'd like : NLO massive/LO massive (Alpgen)
- CDF has measured Wbb and finds a factor 1.5±0.4 to multiply matched Alpgen to agree with data

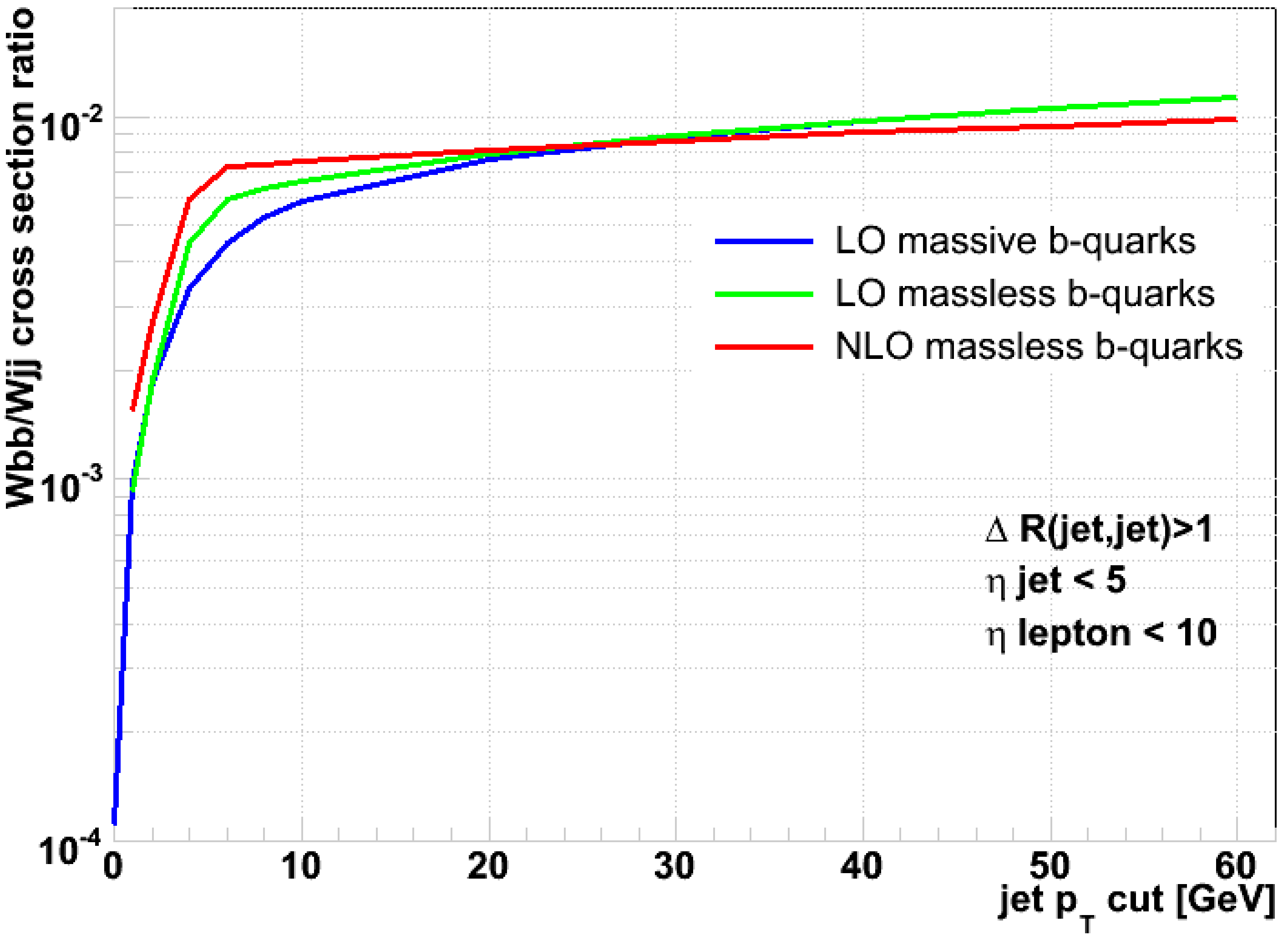
A note on Wcc: even though Wcc is not calculated explicitly in MCFM, it has the same production mechanisms as Wbb. And since Wcc is a really small fraction of Wjj (few%), we can treat Wcc/Wjj the same way as Wbb/Wjj before tagging (with some caveats)

MCFM Wbb/Wjj ratio



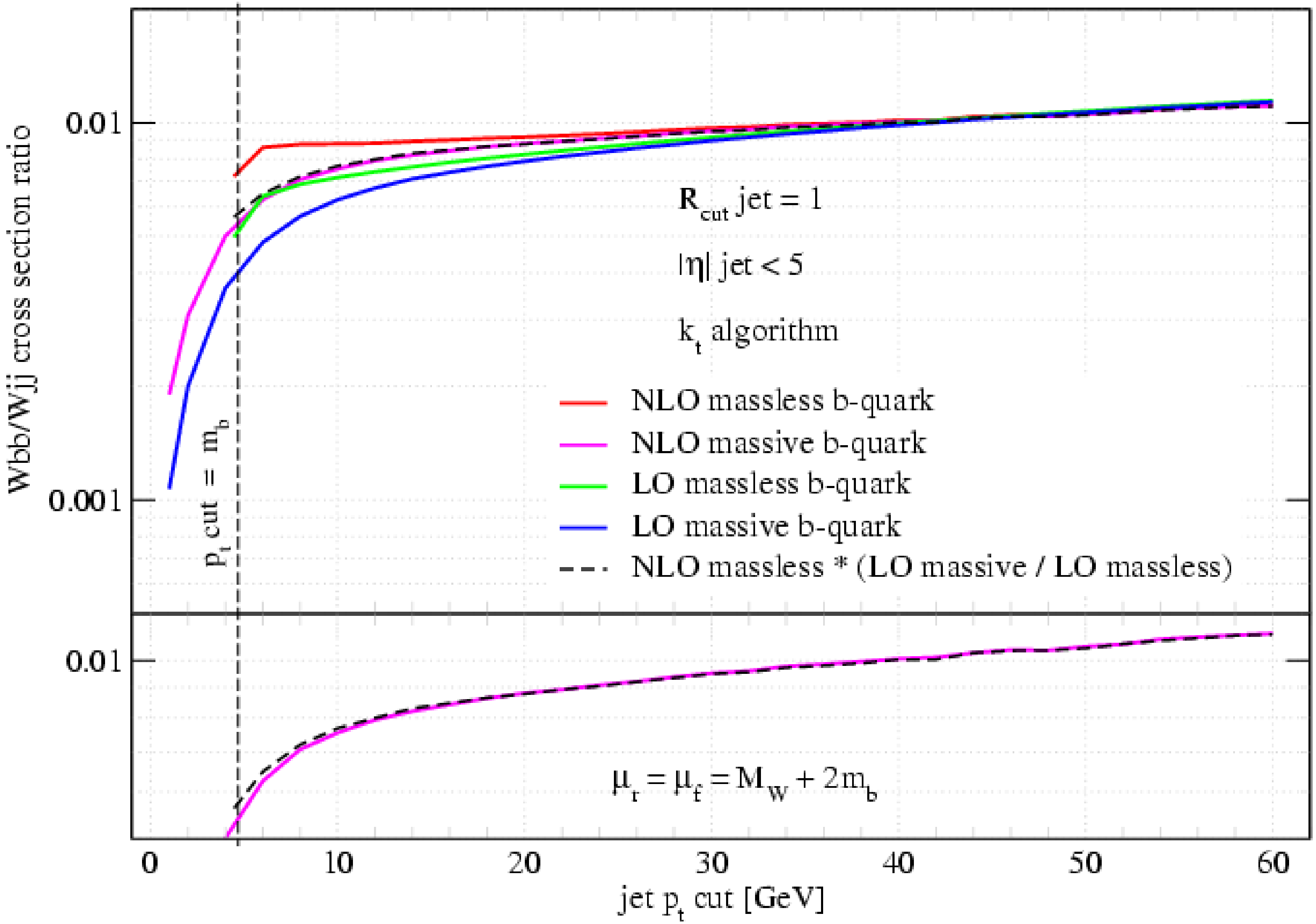
- Adding b mass to LO distribution decreases σ(Wbb)
- The same effect can be expected for NLO (hep-ph/0606102)

Wbb/Wjj ratio with less jet merging



- NLO massive should lay somewhere between red and green
- Flipping back and forth from previous page, we can see the ΔR(jet,jet) cut effect: Wjj k-factor is bigger at 1 than at 0.4

NLO Wbb/Wjj with massive b's



- Plot kindly provided by D. Wackeroth et al. (hep-ph/0606102)

massive NLO = NLO massless * LO(massive)/LO(massless)

Wbj NLO production

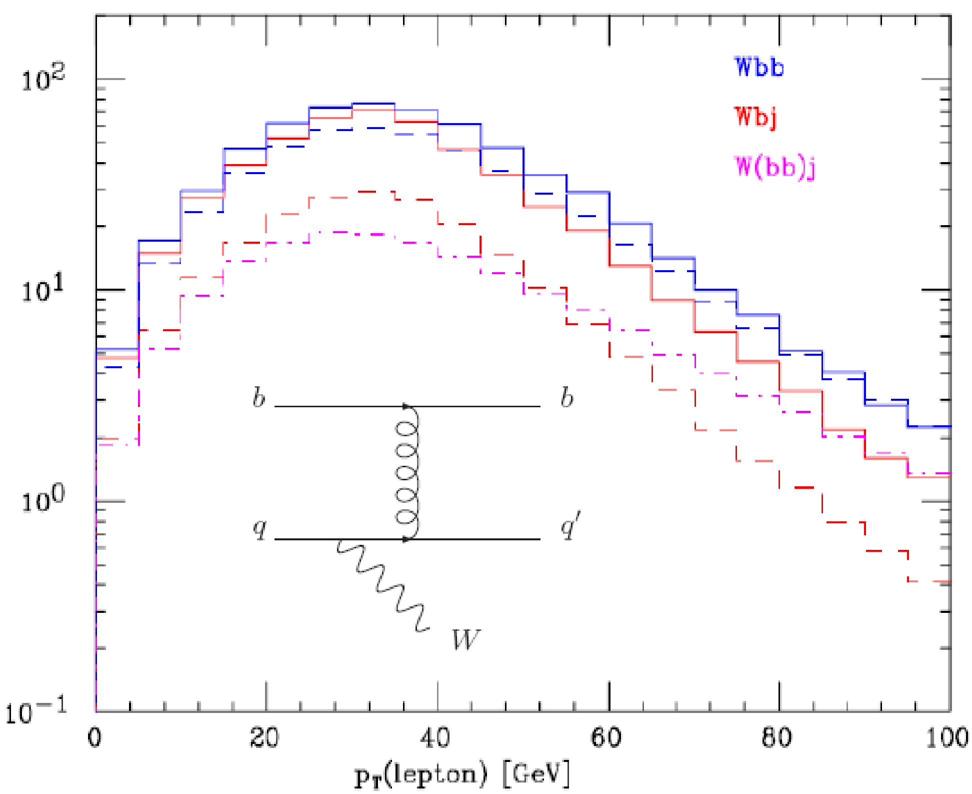
- Most recent MCFM calculation (Willenbrock et al. hep-ph/0611348)

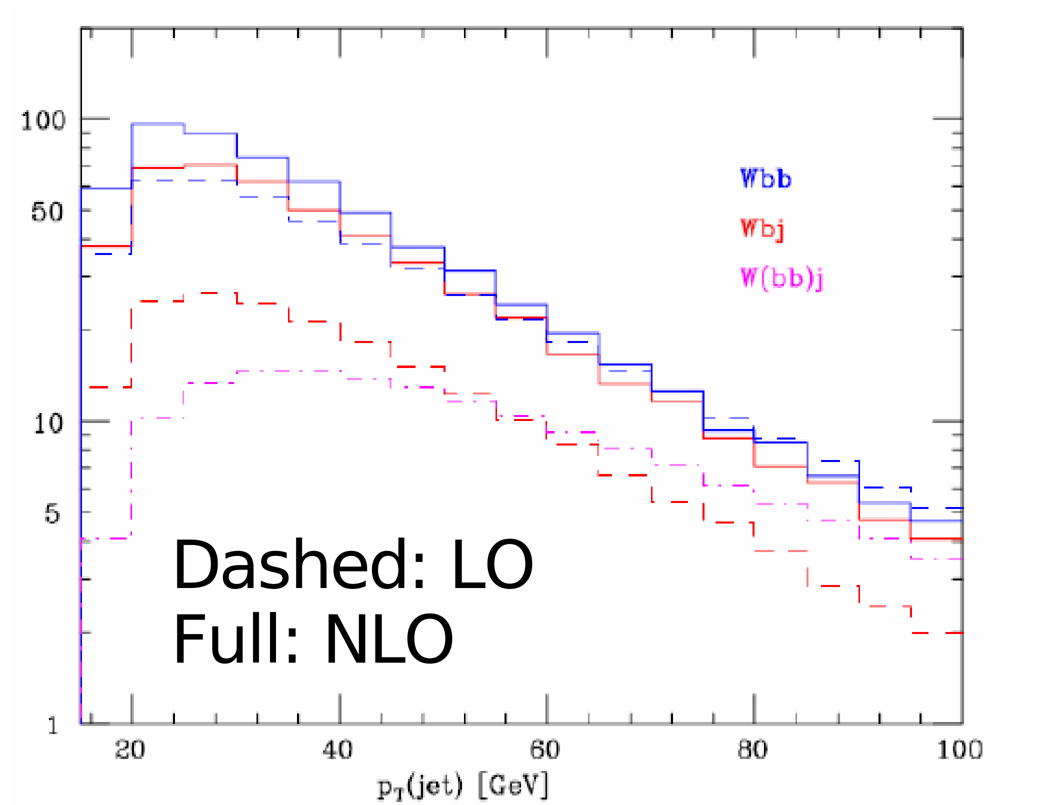
	(LO) NLO Cross sections (pb)				
Collider	Wbj	$Wb\bar{b}$	$W(b\bar{b})j$	$Wbjj$	$Wb\bar{b}j$
TeV $W^+(=W^-)$	(1.06) 2.54	(2.48) 3.14	0.89	0.18	0.65
	Wjj			$Wjjj$	
TeV $W^+(=W^-)$	(261) 290			39	

Wbj has large k-factor!

Wbj is produced in Wbbj in Alpgen

- Wbj behaves similarly to Wbb: also comparable in size!





Conclusions and open questions

- MCFM can be used to obtain NLO cross sections
- Interpretation of results to apply to matched Alpgen is difficult, since LO MCFM and LO Alpgen are difficult to “match”
- Need to take massive b effects into account: prescription ready
- Loosening MCFM parton cuts changes significantly the result
- Wbb k-factor has strong dependence on b jet p_T: we should parametrize the HF fraction as a function of jet p_T
- Wbj has large k-factor, but behaves like Wbb. Study it separately? Covered by Wbb k-factor?

Possible solutions:

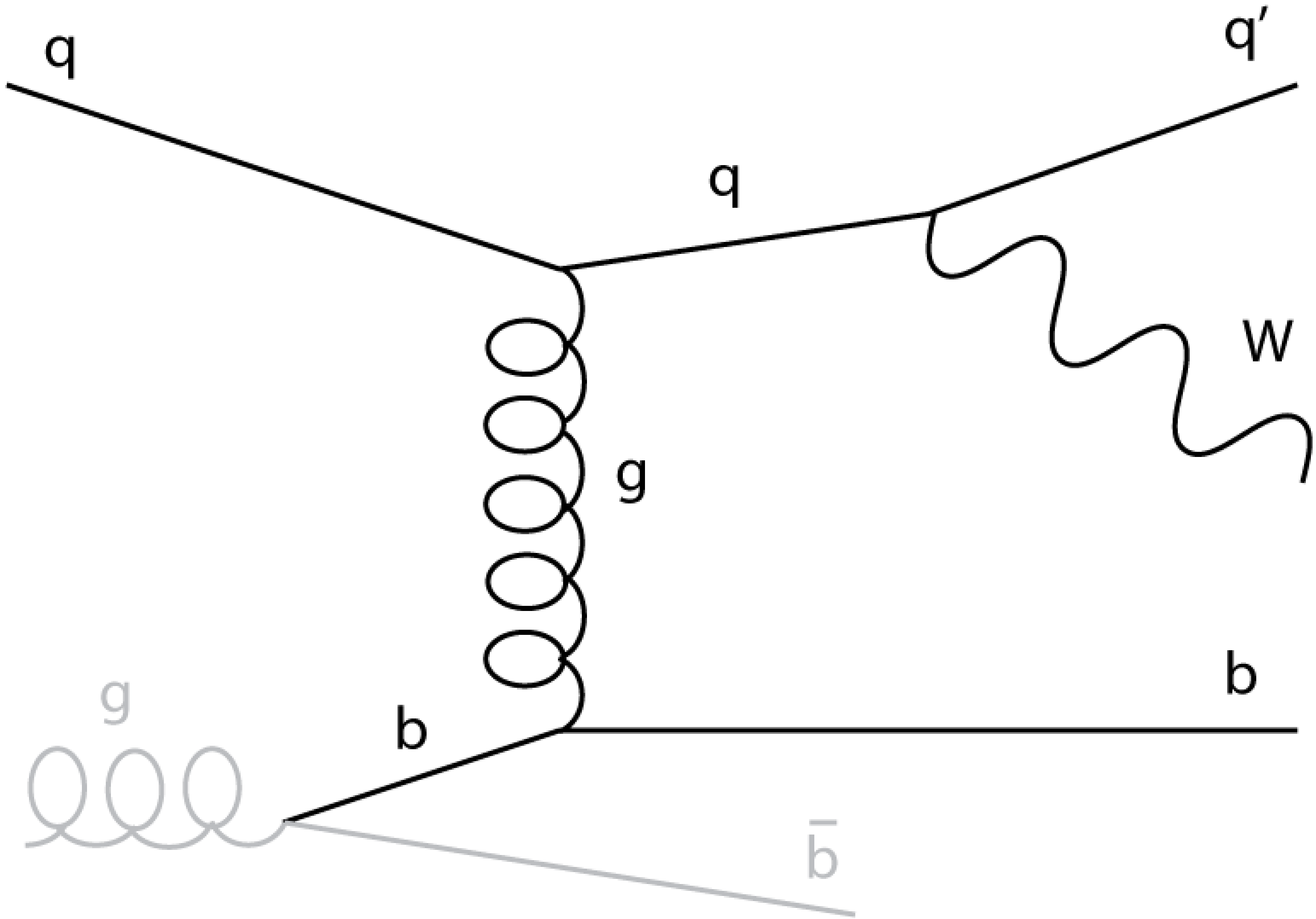
1- If Alpgen/MCFM agree at LO, use NLO MCFM with mass effects taken into account

2- Use the data to measure HF fraction (Wcc? shape dependence?)

3- Use the data to measure Wbb (Wcc? shape dependence?)

What errors are associated to each possibility?

Extra slides



Check list: things to do

- Latest MLM version effect of ickkw=1,0
- How to match Alpgen and LO MCFM with massive b: compare MCFM and Alpgen to check agreement
- Shape dependence of k-factors
- How to determine the errors on a k-factor from MCFM? Comparing to what?
- How to determine the errors on a k-factor measured in data? What effects should we look at?
- Study Wc k-factors if/when available in MCFM
- Study Wbj process in Alpgen and make sure its large k-factor is covered
- ...

Some basics

- k-factor = σ_{NLO}/σ_{LO}
- HF ratio = σ(Wbb)/σ(Wjj)
- I'm running MCFM v5.1 with native PDFs and ewscheme=+1
  - $\alpha_s(M_Z)$ and $\sin^2\theta_W$ are calculated from other fixed EW parameters, like Alpgen 2 does
  - Factorization and renormalization scales: $\mu^2 = M_W^2 + p_T(W)^2$
- The k-factors are calculated with CTEQ6M (NLO PDF) for σ_{NLO} and with CTEQ6L1 (LO PDF) for σ_{LO}, as was done before.
  - Both are massless b's caculations
  - No big difference if I use CTEQ6L1 (LO PDF) for σ_{NLO}
- MCFM can give you:
  - Wbb LO (with massive b's)
  - Wbb NLO (with massless b's), but no NLO with massive b's
  - Wjj NLO and Wjj LO, but no Wcc (Wcc is included in Wjj)

Comparison with p14 numbers

- Derived by Thomas Nunnemann here
- He used MCFM v3.4.5 and CTEQ5L (for LO) and CTEQ5M (for NLO)
- My numbers use v5.1 and CTEQ6M (for NLO) and CTEQ6L1 for LO

p14 Higgs Alpgen parton cuts:

pT(parton) > 8 GeV

|eta(parton)| < 3.0

DeltaR(parton,parton) > 0.4

	Thomas		Aran	
	Wjj	**Wbb**	**Wjj**	**Wbb**
Sigma LO [pb]	90.168+-0.126	0.883+-0.003	112.774+-0.177	0.880+-0.003
Sigma NLO [pb]	135.180+-0.844	1.925+-0.010	137.584+-0.142	1.445+-0.006
K-factor	1.499+-0.005	2.179+-0.004	1.220+-0.014	1.642+-0.012

From Thomas Nunnemann

- With Alpgen 2.06, massive b-quarks

- σ given for one W charge and one l flavor only

Alpgen, `ickkw=0`, no b-cut	2.15 pb	
Alpgen, `ickkw=1`, no b-cut	4.07 pb	p17 production: 3.98 pb
Alpgen, `ickkw=0`, w. b-cut	0.81 pb	
Alpgen, `ickkw=1`, w. b-cut	1.23 pb	
MCFM, LO, massive b, w. b-cut	0.78 pb	
MCFM, LO, massless b, w. b-cut	0.92 pb	
MCFM, NLO, massless b, w. b-cut	1.52 pb	$\rightarrow$ K-factor: 1.65