Method 2 at NLO

(an update of work in progress with John Campbell)

-1st presentation on 4/25/03

-update on 8/1/03

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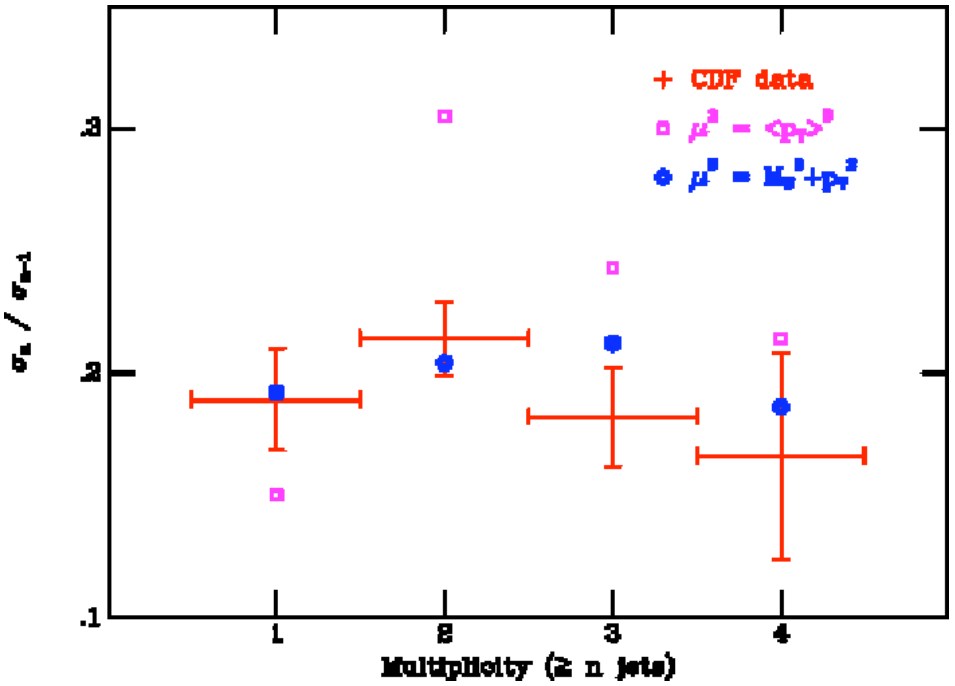
Lepton + jets meeting

Reprise

- It's important to understand QCD production of W + jets, Wbb + jets, as backgrounds to tt, single top, Higgs and other possible new physics
- Ideally, we would use NLO calculations for all cross sections of interest
  - this is the first order that normalization can be taken seriously
  - but current state of the art is W + 2 jets, Wbb
  - although some leads towards *mass production* of NLO multi-parton final states were developed a the Durham workshop
    - many techniques
    - *"Let a thousand flowers bloom"* N. Glover
- We have many useful tools (ALPGEN, MADGRAPH, COMPHEP, GR@PPA) but they're all at leading order (with some higher order terms included through their coupling to HERWIG/PYTHIA)
  - and now we have Steve and Peter's implementation of the CKKW interface
- Also, Z + jets/Zbb + jets are potentially useful for *normalization* but statistics are sparse
- Scale dependence greater for higher jet multiplicities
  - can estimate the effects of higher order terms (in an ad hoc manner) by changing the scales

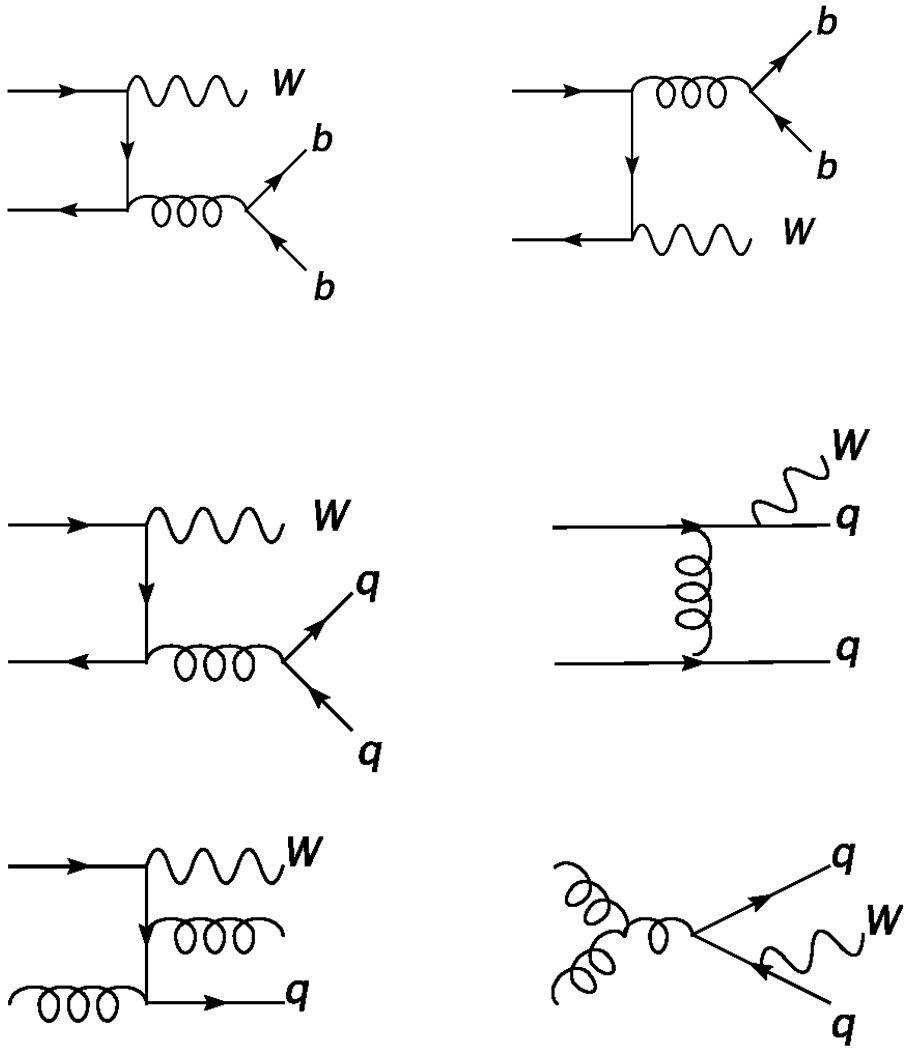
Method II

- In Method II, we take the ratio of LO Wbb + n jets to W + (n+2) jets and then multiply the resulting ratio by the W+(n+2) jets data to determine Wbb+ n jets (and hope that the scale dependence cancels)
  - are the preferred scales different for the two processes?
    - even W+n jet/W+ n-1 jet has different scale dependence
  - are the K-factors (NLO/LO) different for the two processes?
  - difficult to know until NLO calculation done



Topologies

- The topologies are different for Wbb and Wjj production
- …primarily because of the g->bb vertex
- This may affect the relative behaviors at NLO



Scale Dependence at LO and NLO

LO □ has expected monotonic decrease with scale

NLO exclusive scale depen-dence greatly reduced for both processes

Considerable scale dependence remains for Wbb NLO inclusive

~100 GeV reasonably stable

CTEQ6M/L

$\square_s = .118$

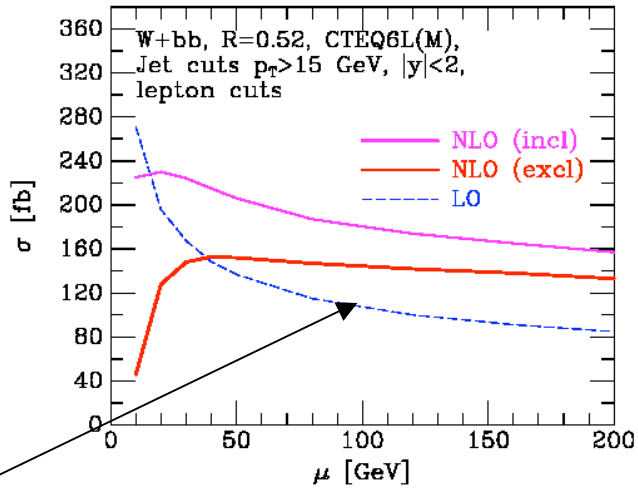
$p_T^{jet} > 15$ GeV/c

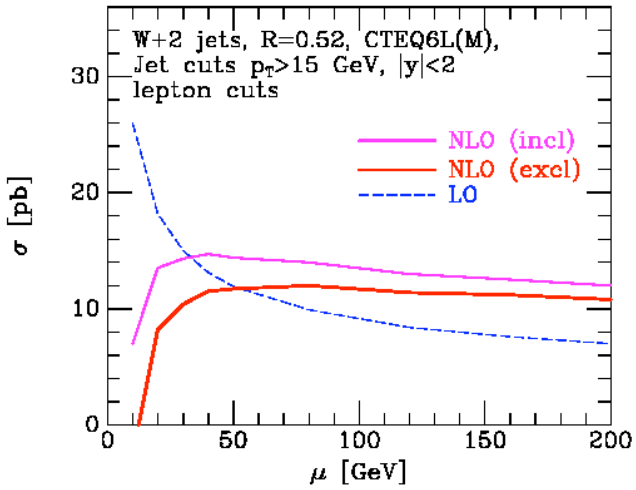
$|\square_{jet}| < 2$

$\square R > 0.4 * 1.3 = 0.52$

Lepton $p_T > 20$ GeV

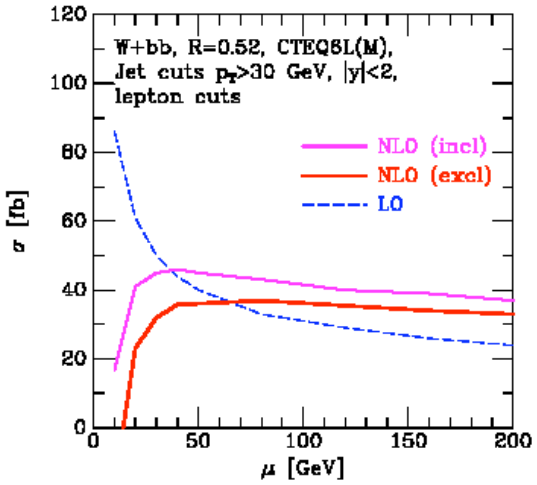
$|\square_{lepton}|<1$, $p_T^{missing} > 20$ GeV

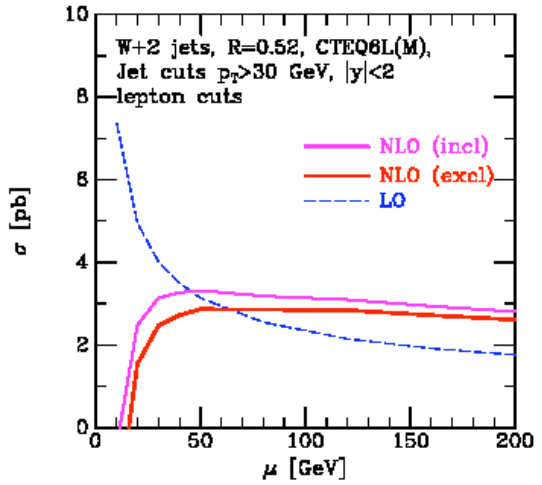


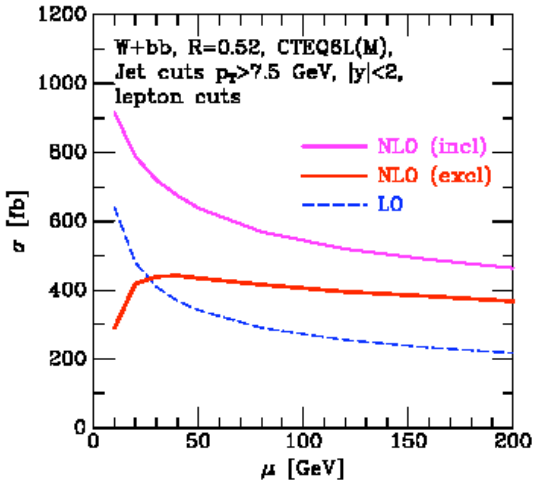


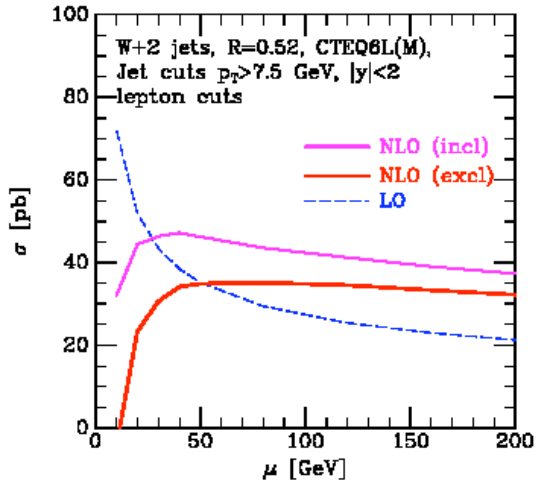
Jet p_T dependence

Inclusive stability improves (degrades) when jet p_T cut is increased (decreased)



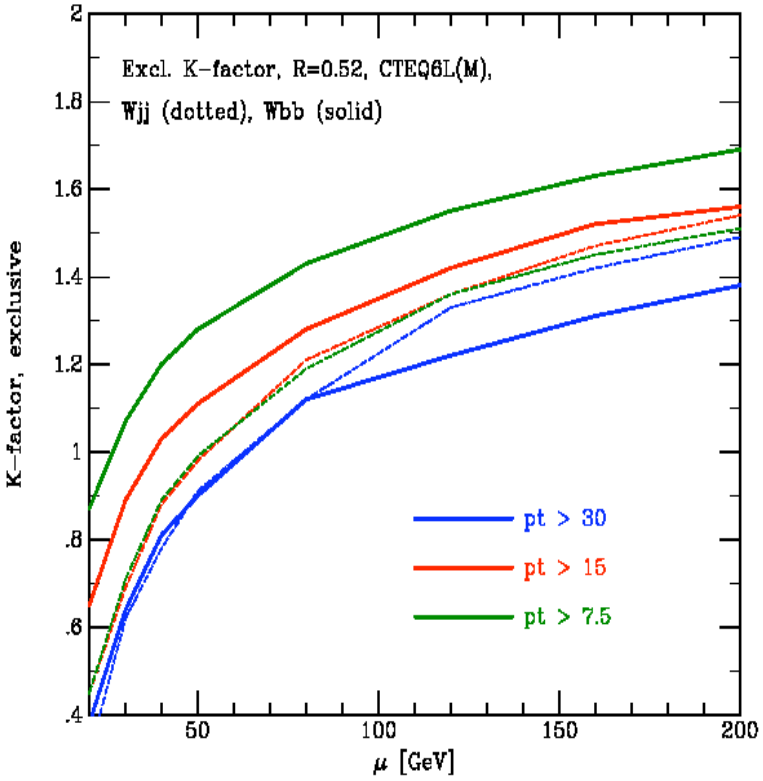






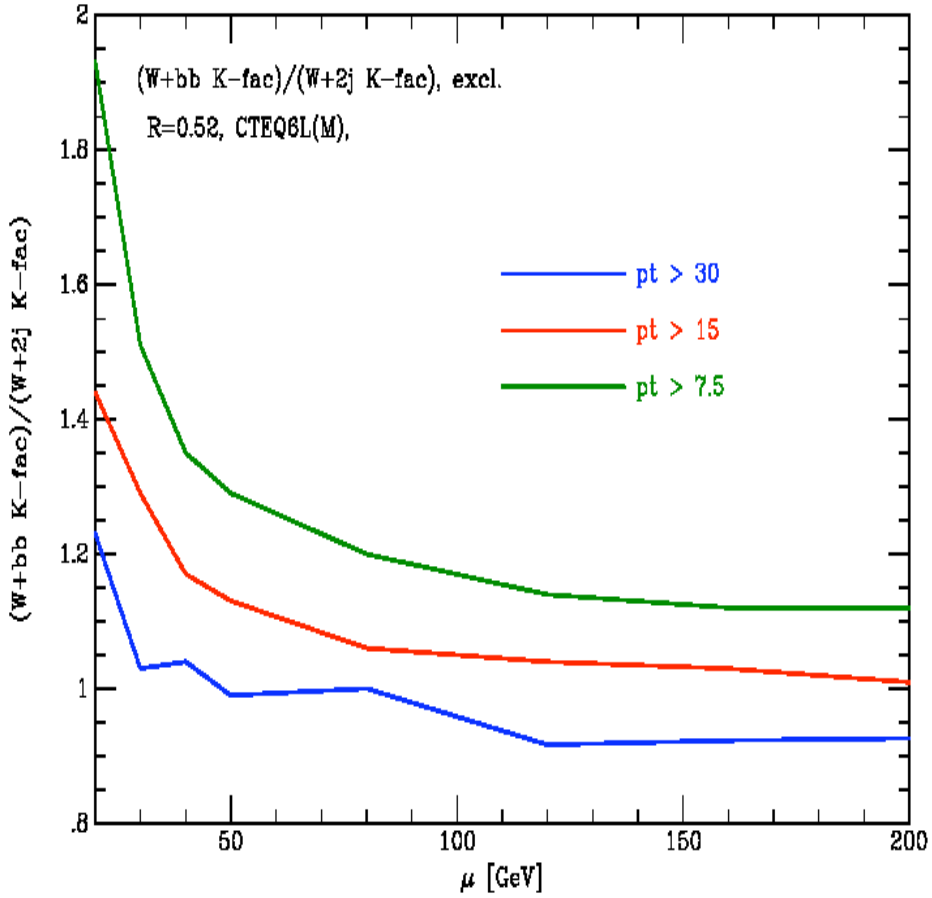
K-factors

- Look at K-factors for both processes as a function of scale
- Note that:
  - K-factors depend strongly on scale
  - K-factors for Wbb depend strongly on jet p_T cut



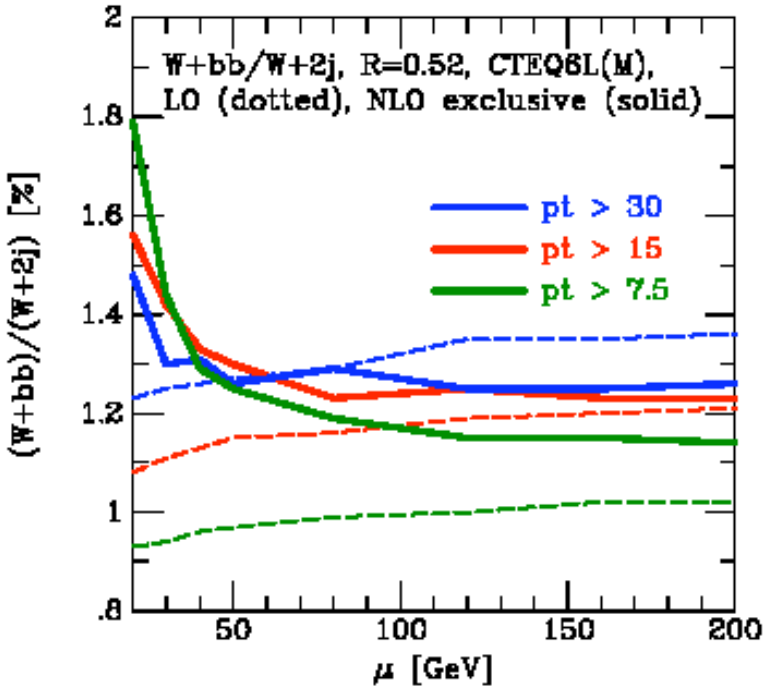
Ratio of K-factors

- It's not the K-factors per se that we are interested in but the ratio of K-factors for the two processes
- Remember, Method II depends on this ratio being near one
  - ok for scales of order of 100 GeV
  - and jet p_T cut of >=15 GeV
    - Method 2 works better with high jet p_T cuts



Wbb/Wjj ratio

- Note that the ratio is very unstable at LO
- …and for low scales at NLO
- At NLO, for scales of the order of 100 GeV, and for a jet p_T cut of 15 GeV, the exclusive ratio is of the order of 1.2(5)%
  - (at LO the ratio is ~1.17)
- That should be a familiar number



It gets confusing

- We assumed a value of 1.2% in the 2 jet bin in Run I
  - but this was after multiplying by an experimentally determined factor of 1.4
    - no factors should be applied to NLO fraction
  - original MC-derived number was ~0.86% (1.2/1.4)
  - in Run II, value obtained is ~0.95% (CDF6570)
- Why is LO number from MCFM ~1.17%?
  - for massless b case
  - for massive case, ratio is reduced to ~1%
  - so roughly consistent with Run II number

TABLE XXVI. Fraction of $W+\geq 1$ jet events with heavy flavor jets as a function of the jet multiplicity.

	$Wb\bar{b}$		$Wc\bar{c}$	
Sample	F_1^b (%)	F_2^b (%)	F_1^c (%)	F_2^c (%)
$W+1$ jet	0.80 ± 0.11		2.01 ± 0.54	
$W+2$ jet	1.28 ± 0.18	1.20 ± 0.38	3.73 ± 1.00	1.40 ± 0.52
$W+3$ jet	1.88 ± 0.31	1.90 ± 0.62	5.31 ± 1.48	2.30 ± 0.91
$W+\geq 4$ jet	3.54 ± 1.06	2.40 ± 0.77	6.08 ± 2.45	3.00 ± 1.13

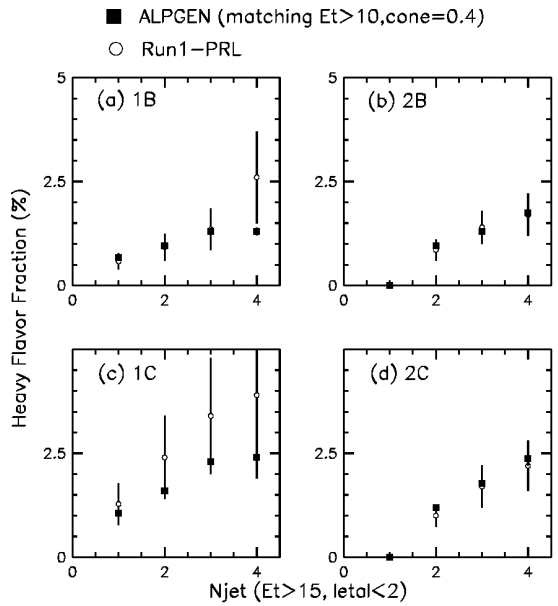
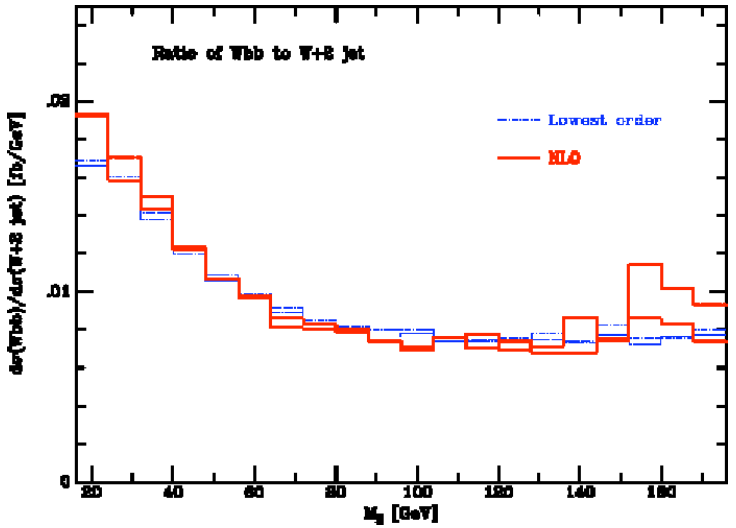
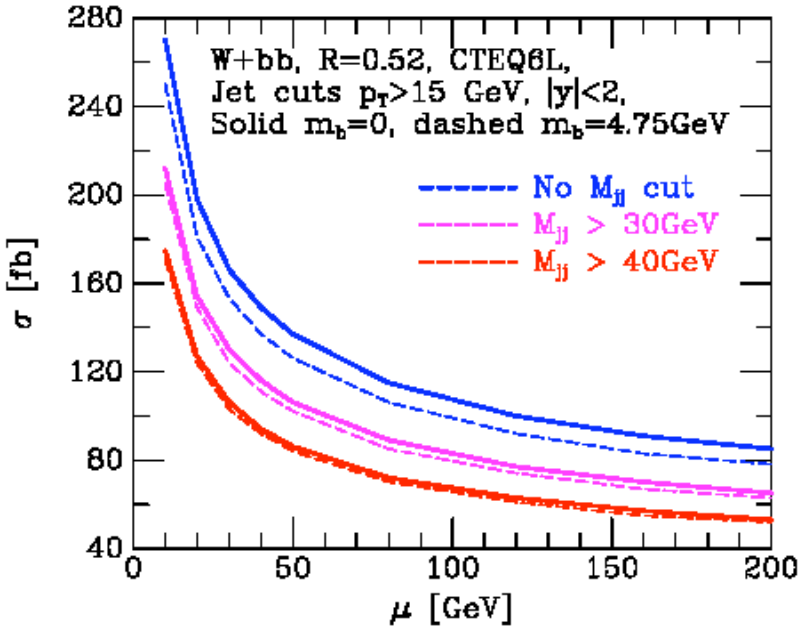


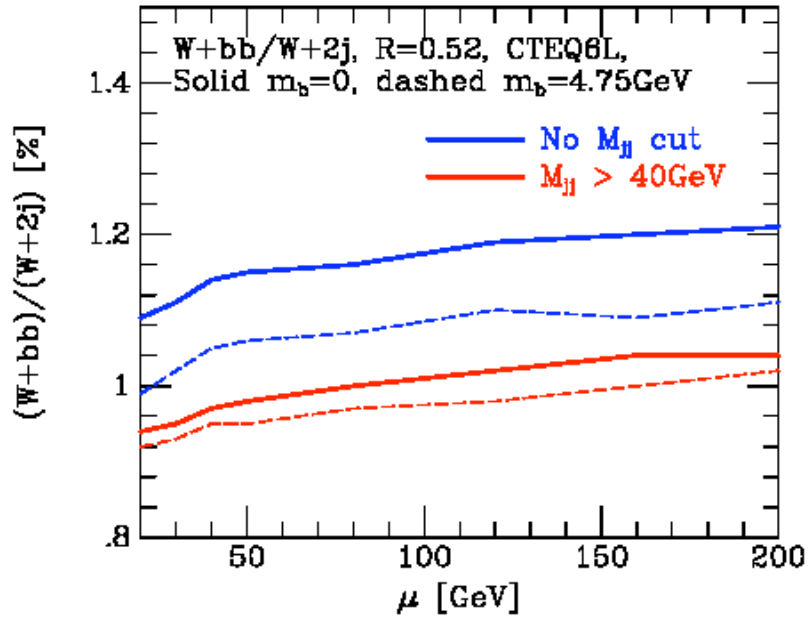
Figure 12: The heavy flavor fractions of WevBB and WevCC as a function of jet multiplicity predicted by ALPGEN.

Effect of a mass cut

bb pair likes to be at low mass; Wbb/Wjj ratio will decrease if a minimum cut is placed on the bb mass

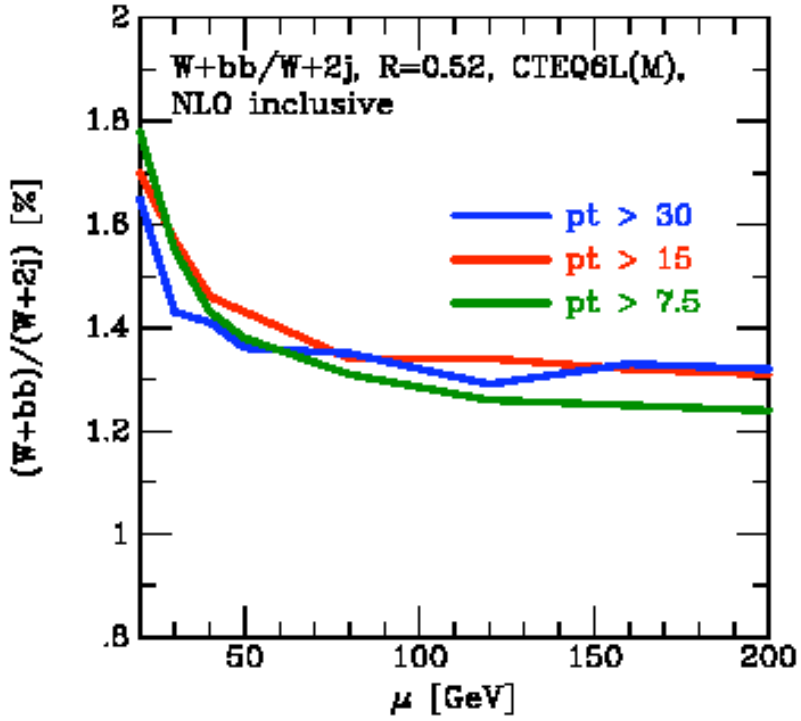






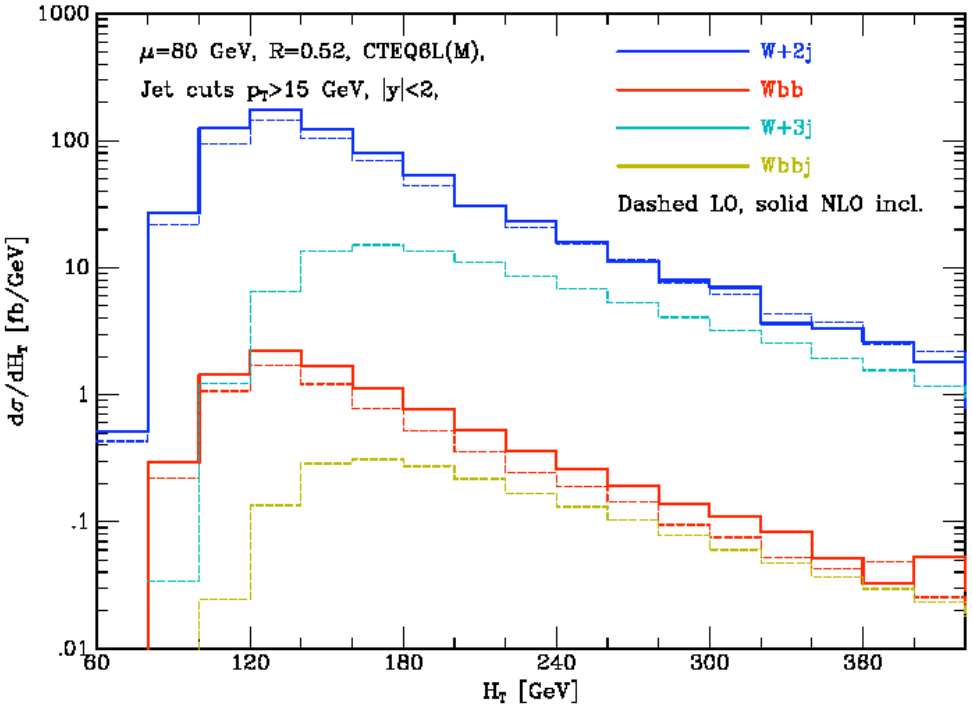
Inclusive Wbb/Wjj ratio

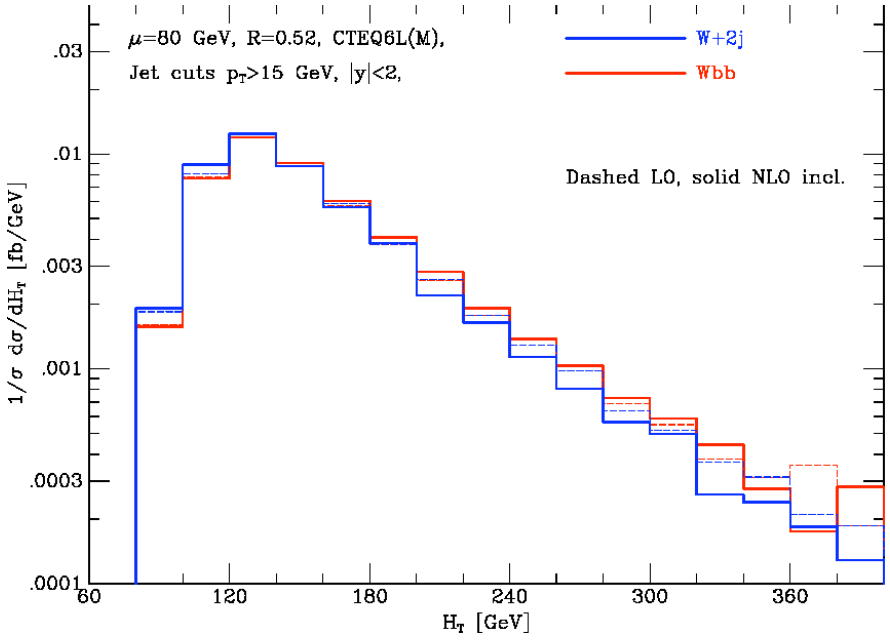
- As expected, ratio increases (to order of 1.35%)



H_T distributions

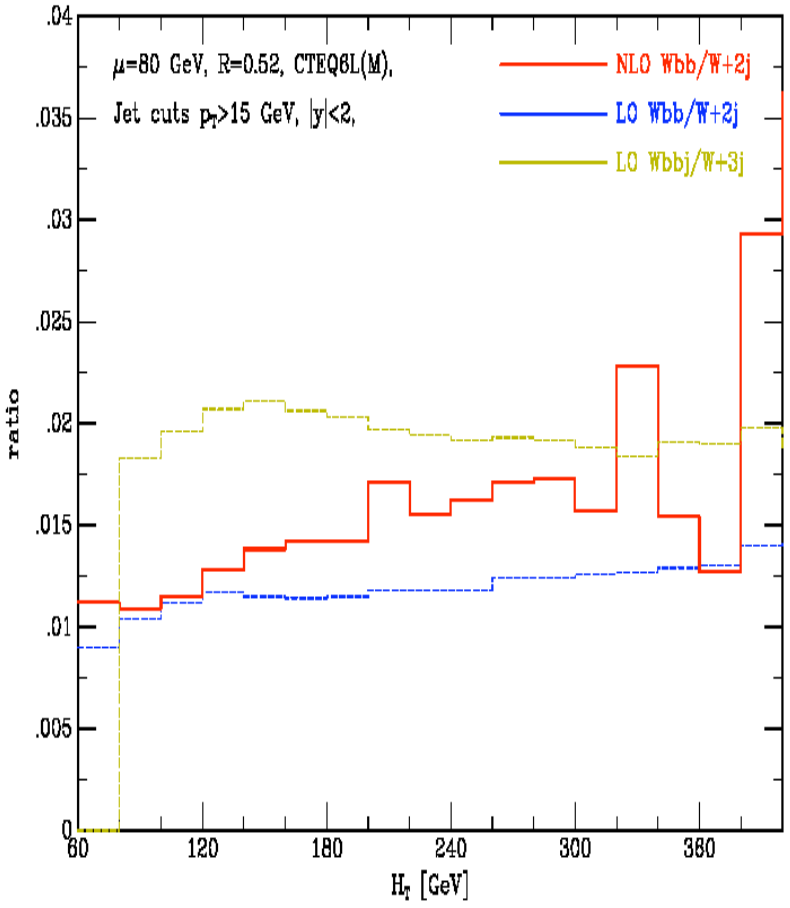
It's also interesting to look at kinematic distributions, as has been done in many of the top analyses. For example, look at H_T for Wbb(j) and Wjj(j) at LO and NLO





Ratios

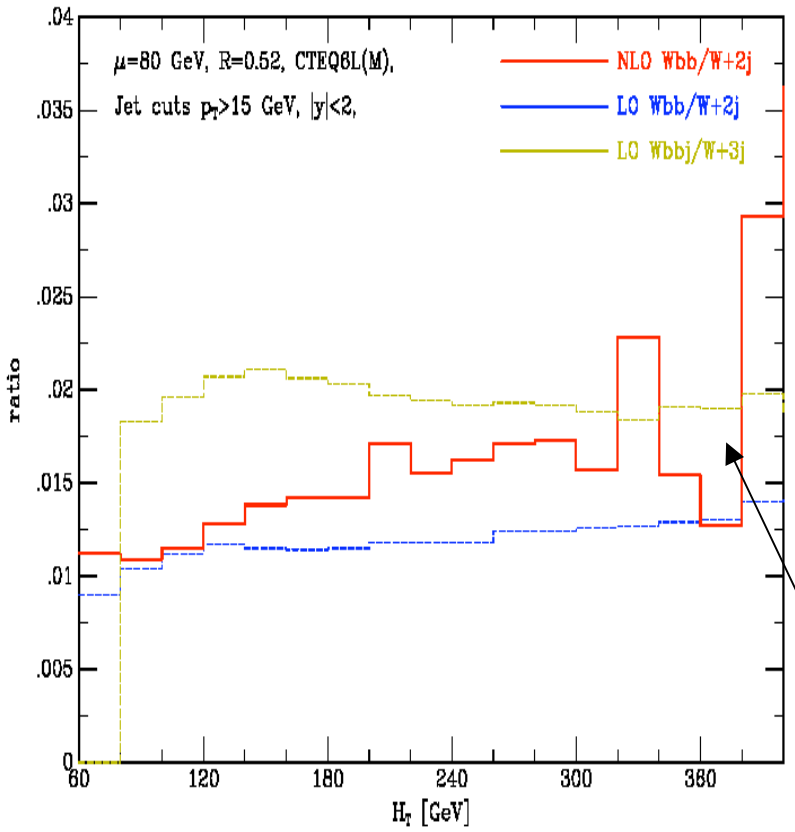
- A keen eye may have noticed on the previous plot
  1. the slopes for Wbb and Wjj are similar at NLO
     - as assumed in the kinematic top analyses
  2. Wjj is steeper than Wbb at NLO though
  3. Wjjj has about the same slope (or is even less steep) than Wbbj
  4. therefore, point 2 is caused by the loop corrections
- Impact on kinematic top analyses still being considered
  - need to confirm/ understand behavior first



then is it fair to generalize to higher multiplicity

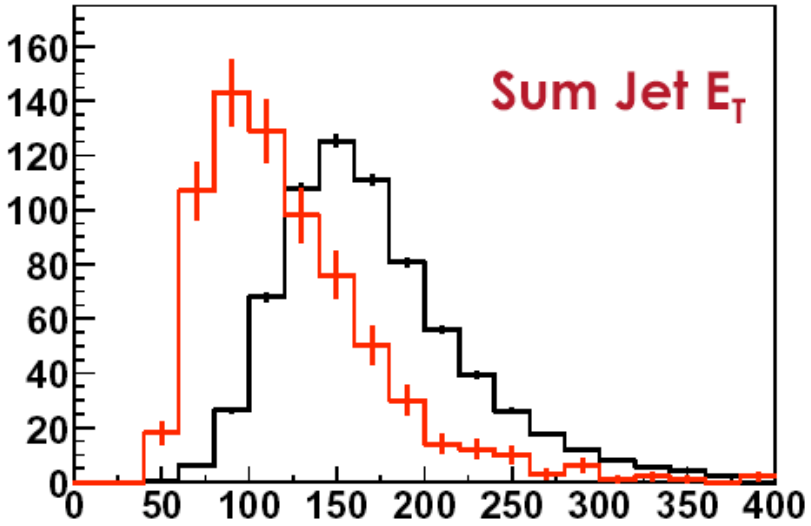
Kinematic analyses

from CDF6503



Wbb (stand-in for all backgrounds)

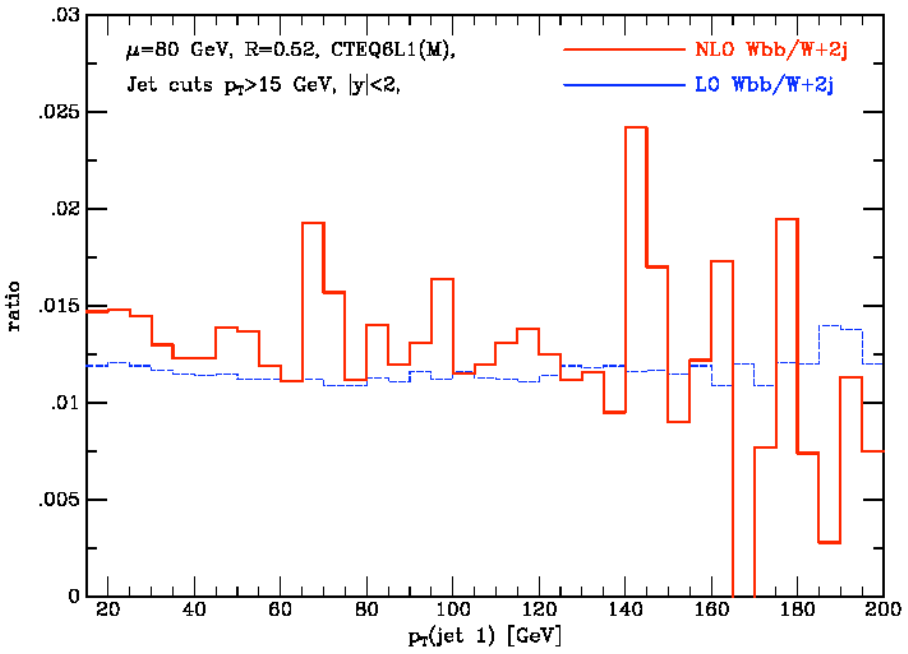
ttbar

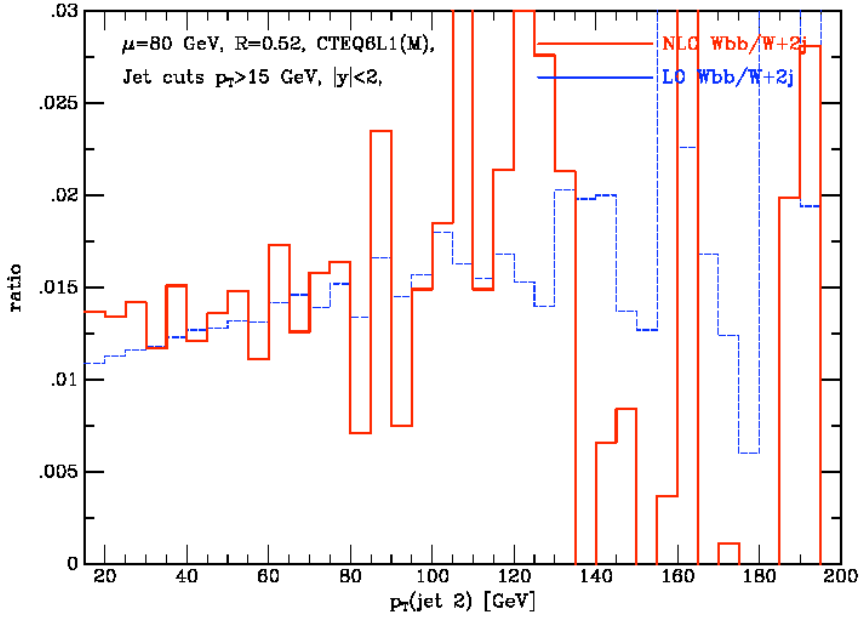


need more statistics at high H_T to fully understand ratio

Jet 1, Jet 2 behaviors

- Low statistics so far





Plans (from Presentation on 8/1/03)

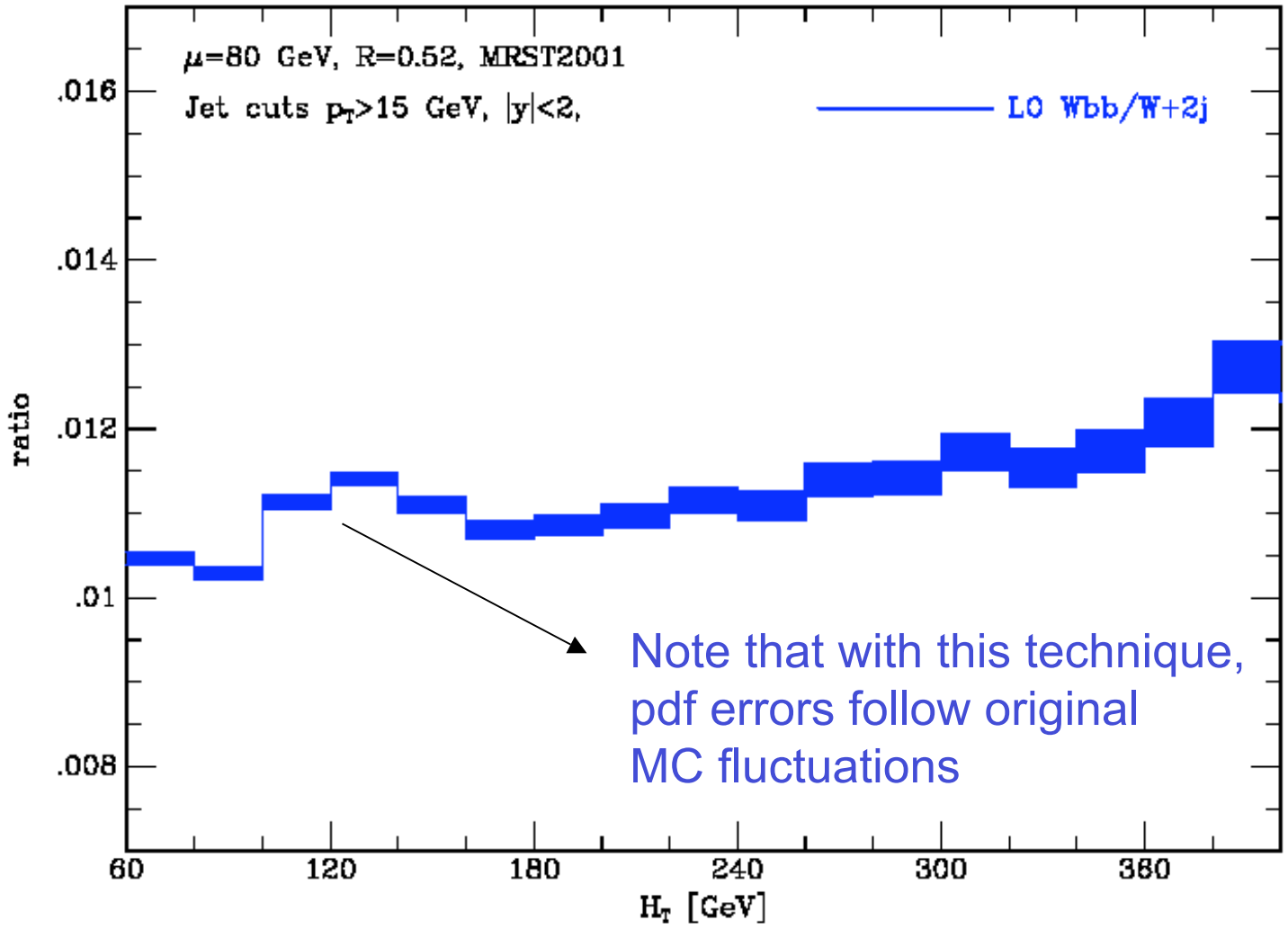
- Finish calculations, comparisons and write up as a CDF note (->almost finished) and then as a publication
  - look at effects of different kinematic cuts
    - in progress; looking at other variables than H_T
    - will work with Taka and Mel and Robin to compare predictions to data where possible
  - bb merging issues
    - in progress; looking forward to ability to look at 2 secondary vertex tags in one jet in data
  - separation of renorm and factorization scales
    - finished; needs to be tested
  - inclusion of pdf uncertainties
    - from CERN MC workshop, an improvement to LHAPDF to allow for all error pdf's to be held in memory at same time
    - calculate cross section using central pdf; store pdf luminosity for each event for all error pdf's
      - can mean order of magnitude increase in speed
    - **finished (in beta version at least); after de-bugging will be in new version of MCFM**

PDF Uncertainties

- Les Houches accord #2 (LHAPDF)
- Using the interface is as easy as using PDFLIB (and much easier to update)
- First version has CTEQ6M, CTEQ6L, all of CTEQ6 error pdfs and MRST2001 pdfs
- See pdf.fnal.gov
- LHAPDF has now been handed off to Durham who will provide support in perpetuity

- call InitiPDFset(*name*)
  - called once at the beginning of the code; *name* is the file name of external PDF file that defines PDF set
- call InitPDF(*mem*)
  - *mem* specifies individual member of pdf set
- call evolvePDF(*x,Q,f*)
  - returns pdf momentum densities for flavor *f* at momentum fraction *x* and scale *Q*

Example (but a meaningless one)



Thinking about next ME/MC meeting

- Last meeting was in April (2 days)
- Number of new things to talk about
  - comparisons of CKKW implementation to CDF/D0 data
  - Method 2 at NLO studies
  - MC @NLO
  - new LHAPDF
  - …
- One possibility is Thursday Nov 13 (right after top mass workshop)
  - but it's an on-week; will people come? (9 AM - 3 PM)
  - can we show CDF data compared to CKKW by that time?

Contributions to higher jet multiplicities for $Wb\bar{b}$ + jets production

1: qq'->Wbb
2: qg->Wbbq'
3: gg->Wbbqq'
4: qq'->Wbbq''q'' + etc
5: qg->Wbbq'q''q'' + etc
6: gg->wbbqq'q''q'' + etc

qg enters for Wbbj
gg enters for Wbbjj
for Wbbjj, qg and gg are ~10% of total tree level cross section

Can we make any statements about K-factors for 3 and 4 jet final states for Wbb compared to W + jets?

Process	NJ=2	NJ=3	NJ=4	NJ=5	NJ=6
1	360	68.6	10.4	1.46	0.20
2	___	37.6	12.1	2.63	0.47
3+4	___	___	4.3	1.66	0.41
5	___	___	___	0.085	0.036
6	___	___	___	___	0.00038
Total	360	106.4	26.8	5.84	1.11

from hep-ph/0108069, mlm et al