QCD group summary

J. Huston, for the QCD conveners

QCD group

- Most of the tools we want to produce/develop in this workshop are QCD-related
  - ME/MC generation
  - NLO
  - jet algorithms
  - pdf's and pdf uncertainties
  - …
  - I don't even know why people are going to the other groups

    -my ed. comment

- Note that there have been a series of previous meetings organized by Steve Mrenna and myself dealing with these types of issues for Run 2
  - cepa.fnal.gov/patriot/mc4run2/index.html

SM Physics

Before we publish new physics at the LHC, we need to understand SM physics. A lot of prior knowledge can come from the Tevatron.

Backgrounds – Measuring and Calculating

At present, we rely on MC for signal and background estimates

There are uncertainties in rates from PDF's, higher order QCD

Most of these do no matter at the moment, They will matter once data appears

The MC/theory tools must match the experiments

Don't forget that the LHC will be a precision machine.

Some processes are not well understood: For these we need flexibility in the modeling

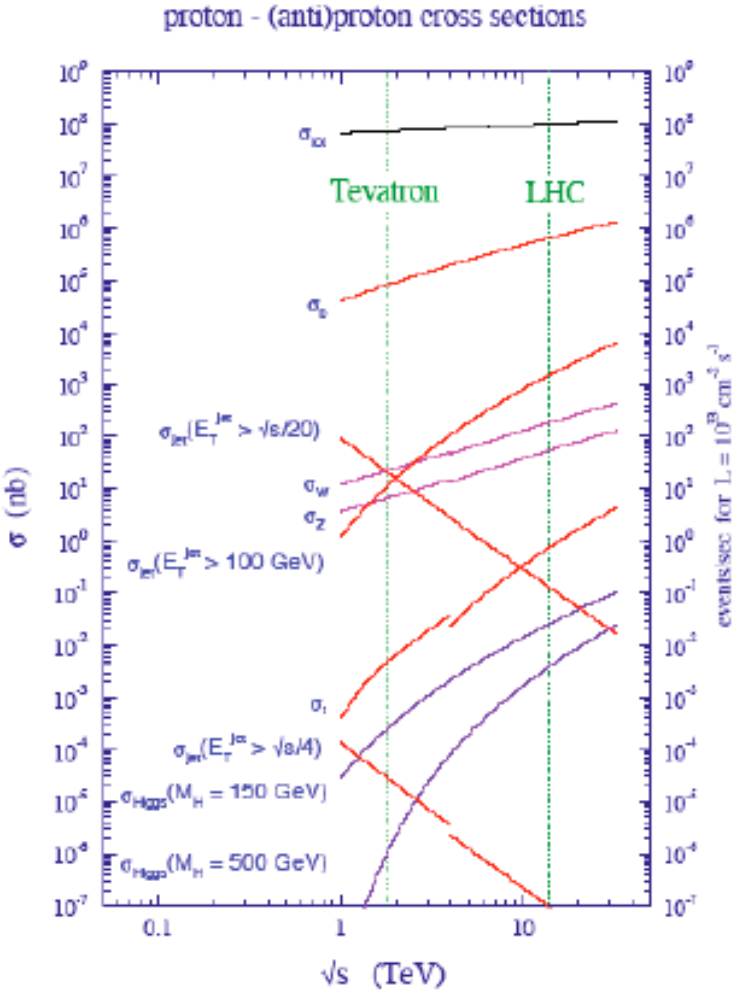
A concern: underlying and min-bias events

Affects process that need forward jet tagging *e.g.* $WW-scattering$ or central jet veto *e.g.* extraction of objects produced by EW interaction

Will be measured once data exists and MC will be tuned to agree... But

Speech

Ian Hinchliffe from Thursday



Physics group goals

- QCD sub-groups
  - pdf's and event classification
    - extraction of pdf's purely at high-momentum transfers
    - establishment of jet contracts between experiments and theorists
    - subtleties and practicalities of jet algorithms
  - hard scattering and hadronization
    - testing of matrix element-parton showering matching
    - underlying event tunes and model development
    - tests of hadronization and tunes/universality of tunes
  - diffraction

- Top and Electroweak
  - top production and decay
  - analysis techniques
  - improved tagging strategies

great deal of overlap

…and that's why much of our time here was spent in joint meetings

Conveners and info

- QCD conveners
  - M. Albrow, F. Chlebana,A. de Roeck, S. Ellis, W. Giele, J. Huston, W. Kilgore, S. Mrenna, W-K. Tung, M. Wobisch, M. Zielinski
- Group website
  - www.pa.msu.edu/~huston/tev4lhc/wg.htm
- Sub-sub-groups
  - PDF's and PDF Uncertainties at the Tevatron and LHC
  - Jet Algorithms and Event Structure
  - Matrix element/Monte Carlo/NLO matching
  - Hadronization Corrections and UE tunes
  - Diffractive Physics

Jet Projects

1. inclusion of jet production in MC@NLO

   Steve Ellis,Bill Kilgore, Stefano Frixione, Joey Huston

   Stefano was deemed a security risk for this meeting, but hopefully the work will continue at Les Houches.

2. Practicing safe exclusive (jet) final states (jet vetos)

   Steve Ellis

3. jet algorithms at the Tevatron and LHC

   -impact of splitting/merging; understanding the effects of splitting/merging at the parton and hadron level

   -impact on boosted systems, e.g. W->jj in high p_T top

   -understanding differences observed in jet reconstruction between CDF and D0 environments

-reconstruct sample of MC events that produce problems in the CDF environment using D0 and LHC algorithms

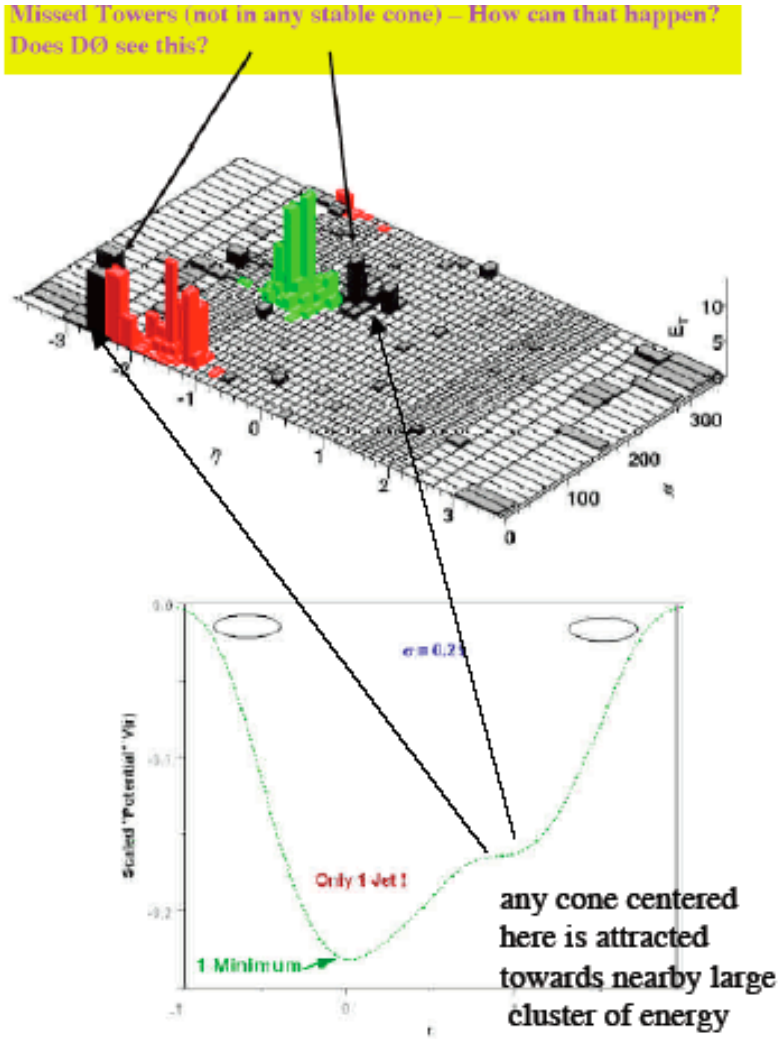
From website

- A stand-alone CDF Fortran/C++ jet clustering routine is available here.
- Some descriptive text from Matthias Tonnesmann is available here.
- The Monte Carlo events that resulted in "dark towers" or "fat jets" in the CDF clustering are available here (along with some descriptive text from Matthias).

Michael Begel, Frank Chlebana, Steve Ellis, Joey Huston, Alison Lister, Matthias Tonnesmann,Markus Wobisch, Marek Zielinski

Jet clustering

- Run II analyses in CDF and D0 use both cone and k_T jet algorithm
- CDF has used both JetClu (Run I) and midpoint (Run II) algorithms; D0 solely midpoint
  - subtle issues (and solutions) regarding use of midpoint algorithm
  - See hep-ph/0111434, S. Ellis, J. Huston, M. Tonnesmann, *On Building Better Cone Jet Algorithms*

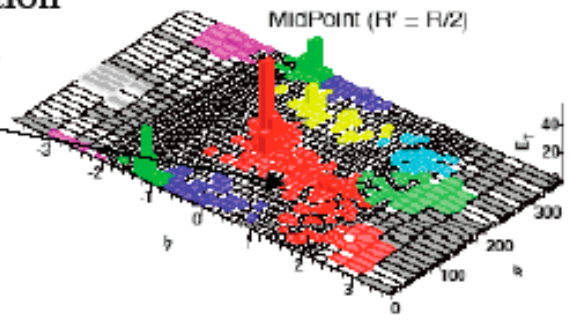


Solution: smaller initial search cones ($R_{cone}/2$)

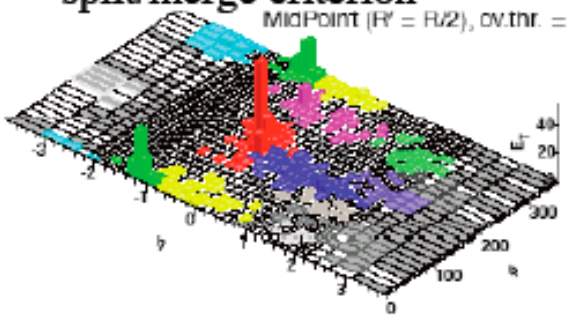
Fat jets

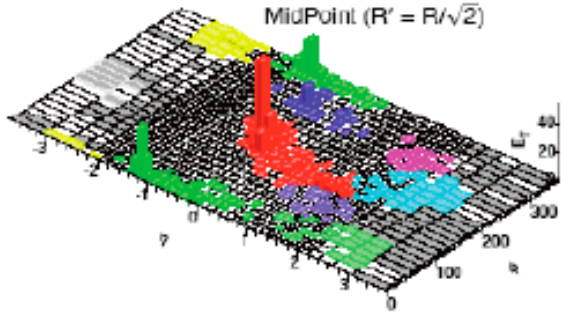
• Run / Event: 151843 / 1723497 (Jet100)

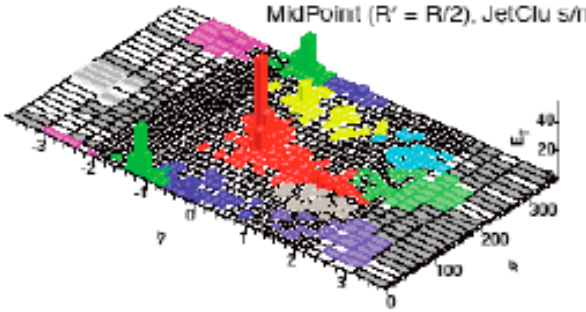
split/merge fraction of 50% can lead to fat jets

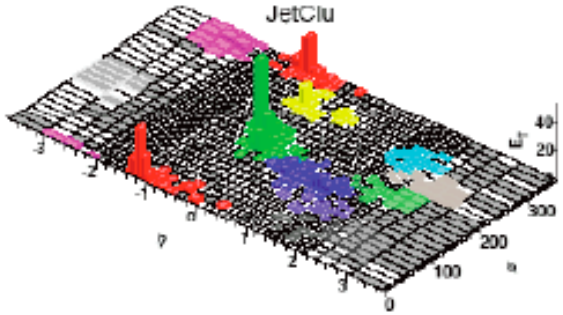


…which is greatly reduced with a 75% split/merge criterion









…may be more of a problem in a high luminosity environment

Jet Projects

3. UE subtraction

-definition of UE + uncertainty for comparisons of data to NLO

Florencia Canelli: UE subtraction uncertainty

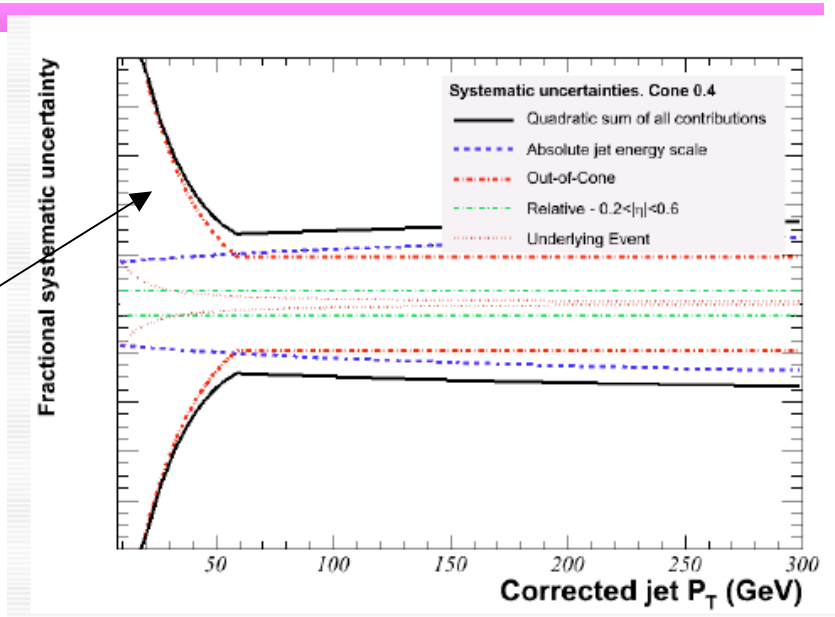
dominant at low E_T

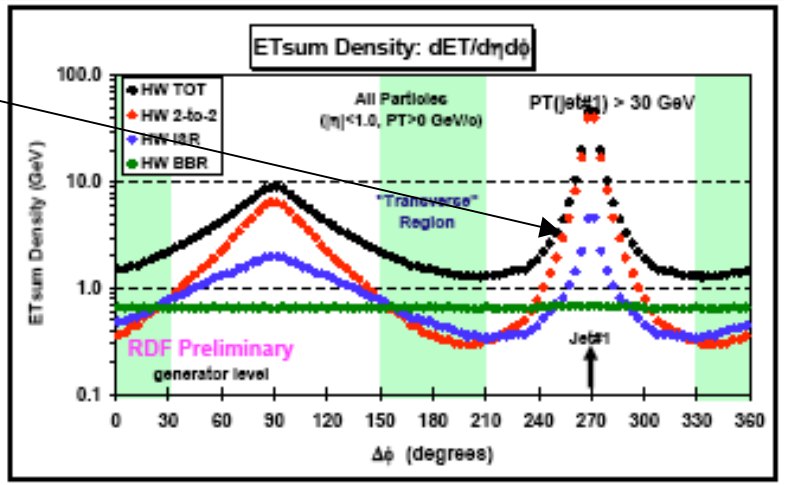
-impact of ISR on jets and jet predictions

->is there an ISR contribution not accounted for by NLO?

-operation in high multiple interaction environment

Rick Field, Joey Huston, Peter Skands





R. Field, TeV4LHC WG meeting in December

PDF projects

1. benchmarks for NLO/NNLO fits (W/Z at Tevatron and LHC)

   Dimitri BourilkovJoey Huston, Pavel Nadolsky

2. validity of NLO DGLAP formalism

   Joey Huston, Pavel Nadolsky

3. pdf uncertainties

   -universal delta_chisquare

   -pdf weighting; impact of uncertainty of Sudakov FF's

   -mis-match between PS pdf evolution and DGLAP?

   -embedding LHAPDF into programs

   Stefan Gieseke, Joey Huston, Pavel Nadolsky, Dimitri Bourilkov. Peter Skands

4. inclusion of Tevatron data in global fits

   "back-of-the-envelope" studies

   -W+c

   -γ +b/c

   -Z+b

   Frank Chlebana, Mario Campanelli, Joey Huston, Pavel Nadolsky

6. heavy flavor pdf's and their uncertainties

   Pavel Nadolsky

W as benchmark

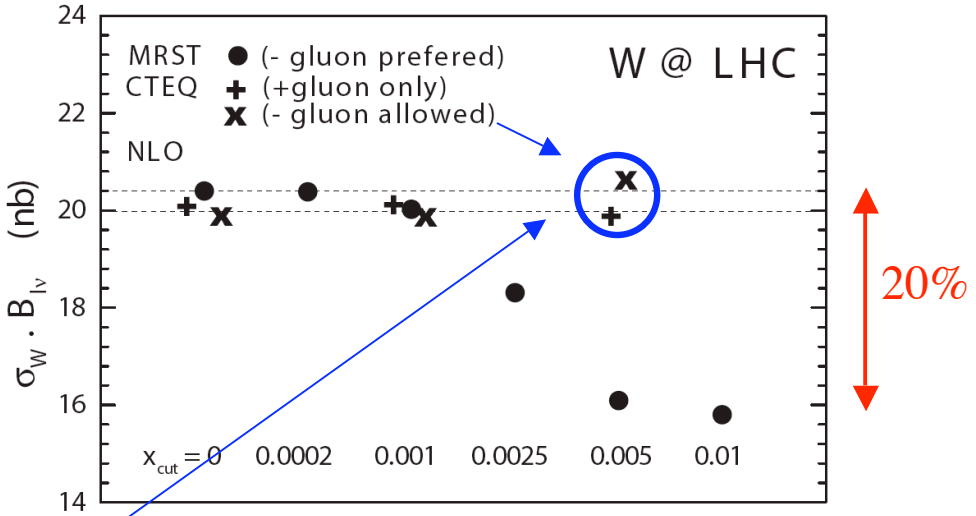
TeV4LHC

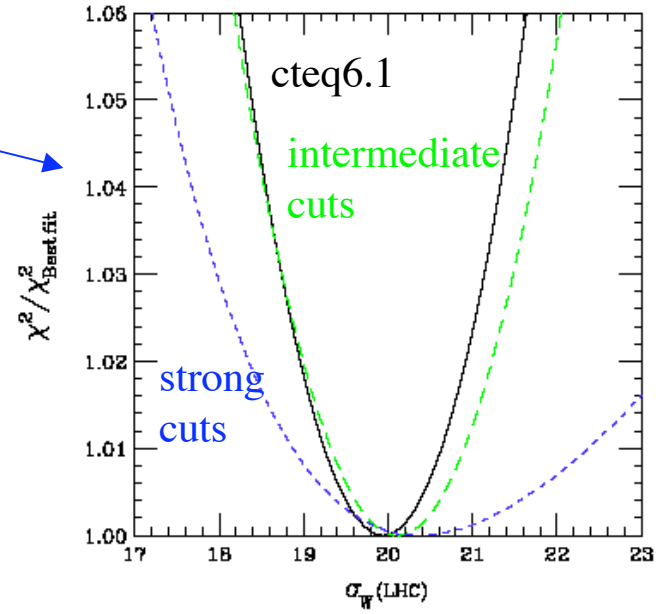
$W \rightarrow l\ \nu$ as luminosity monitor

- Current method based on σ_{inel}(ppbar)= 61.7±2.4 mb @ 1.96 TeV (4%)
- Can we do better using the cross section for $W \rightarrow l\nu$ measurement?
- Recent paper by Frixione and Mangano (hep-ph/0405130) investigate contributions of uncertainties in acceptance calculation to the $W \rightarrow l\nu$ x-sec measurement (currently ~2%)
- Tevatron and LHC would benefit from experimental and theoretical work

Validity of NLO DGLAP

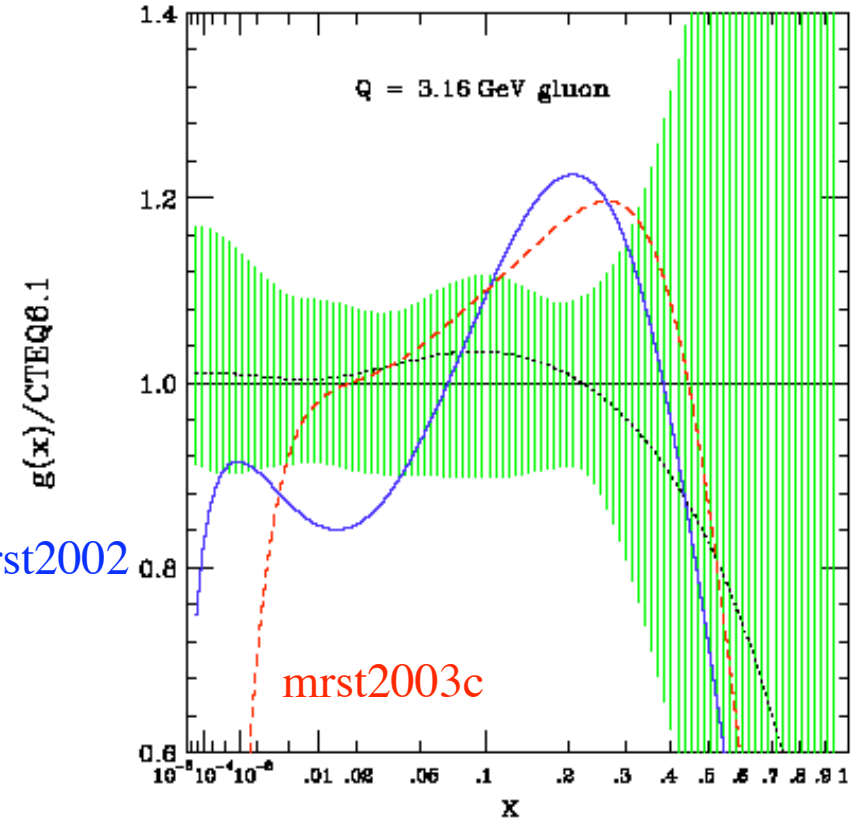
- Is there a *tension* between HERA and Tevatron data requiring NNLO DGLAP to resolve?
  - MRST study: hep-ph/0308087
  - W cross section at LHC drops 20% when data below x=.005 are removed from fit
  - implications for use of W σ as luminosity benchmark
- Recent CTEQ study indicates as more severe cuts are made in x and Q^2 in global analysis, uncertainty on W cross section at the LHC increases but central value remains relatively constant



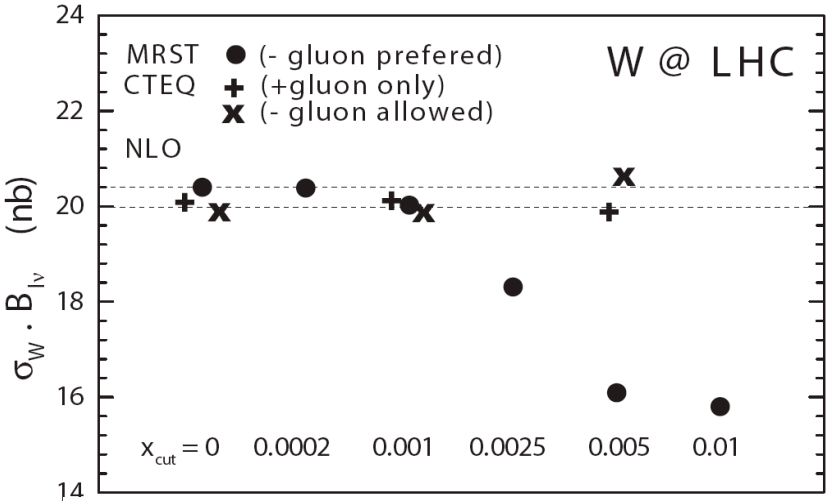


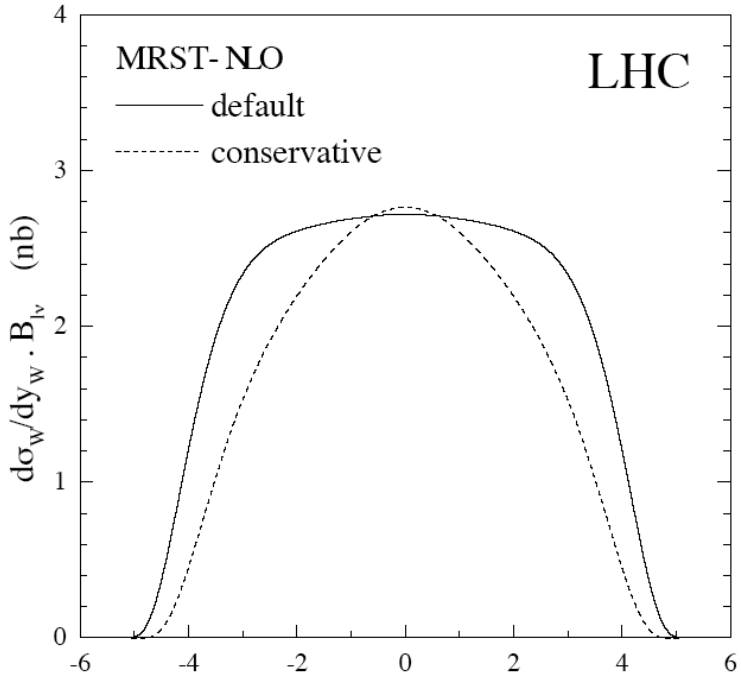
Negative gluon

- Lower cross section in MRST study results from pinched rapidity distribution caused by impact of negative gluon



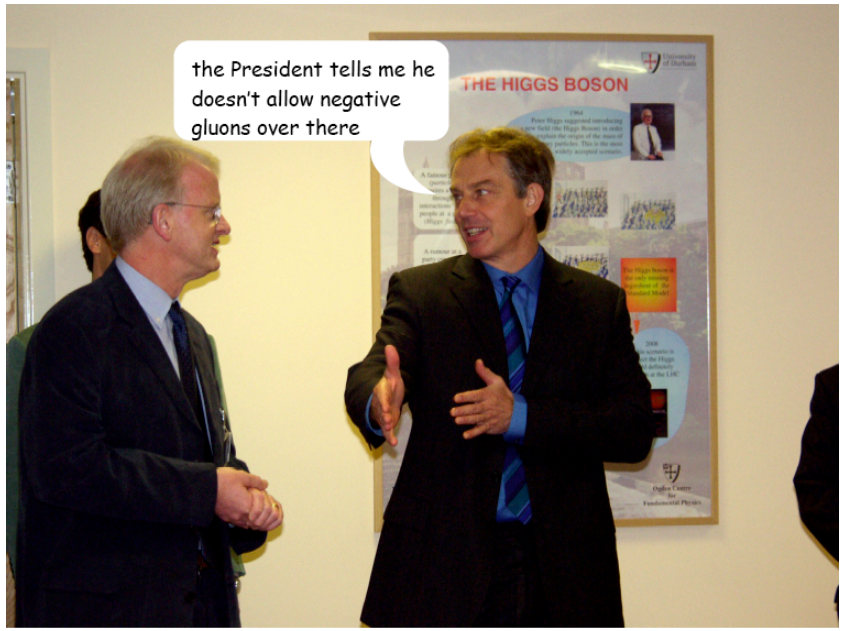
mrst2002

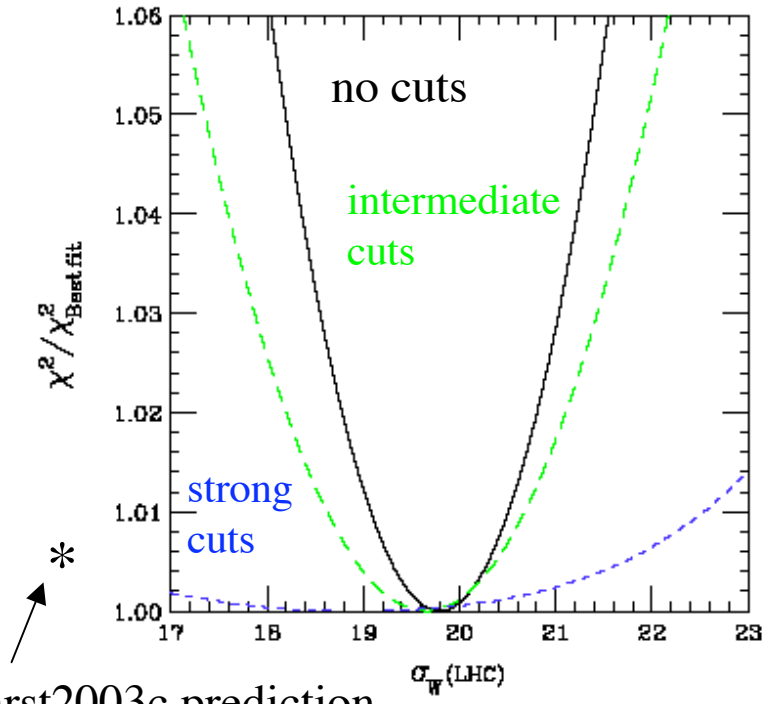




NLO stability

- CTEQ conclusion: if negative gluon allowed, then uncertainty of σ_W increases (dramatically for severe cuts), but again central value remains constant
- No advantage found in fit of allowing negative gluon





mrst2003c prediction

coming soon (Monday) to LANL

February 3, 2005

MSU-HEP-5
CTEQ-5

Stability of NLO Global Analysis and Implications for Hadron Collider Physics

J. Huston, J. Pumplin, D. Stump, W.K. Tung

Michigan State University, E. Lansing, MI 48824

Using pdf uncertainties

TeV4LHC

- PDF uncertainties are important both for precision measurements (W/Z cross sections) as well as for studies of potential new physics (a la jet cross sections at high E_T)
- Most Monte Carlo/matrix element programs have "central" pdf's built in, or can easily interface to PDFLIB
- Determining the pdf uncertainty for a particular cross section/distribution might require the use of many pdf's
- **->LHAPDF**
  - a replacement for PDFLIB as the source for up-to-date pdf's
  - originated by Walter Giele; now maintained by Mike Whalley of Durham

- Using the interface is as easy as using PDFLIB (and much easier to update)
- 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*

Version 3 of LHAPDF

LHAPDF Version 3

released Sept 2004

http://durpdg.dur.ac.uk/lhapdf/ -> http://durpdg.dur.ac.uk/lhapdf3/
http://durpdg.dur.ac.uk/lhapdf2/
http://durpdg.dur.ac.uk/lhapdf1/

older versions are "frozen" and kept available

(1) More PDFs available:

New : ZEUS – LHpdf file using QCDNUM (thanks to Mandy Cooper-Sarkar)
H1 – LHgrid file (thanks to Christian Pascaud)
MRST2003c (nlo and nnlo) – LHpdf and LHgrid files

Legacy: CTEQ4, CTEQ5, GRV98 – all using the original interpolation codes – ie LHgrid files

From talk of Mike Whalley at HERALHC meeting at CERN in October

PDFLIB interface courtesy of Dimitri Bourilkov

Using pdf uncertainties, continued…

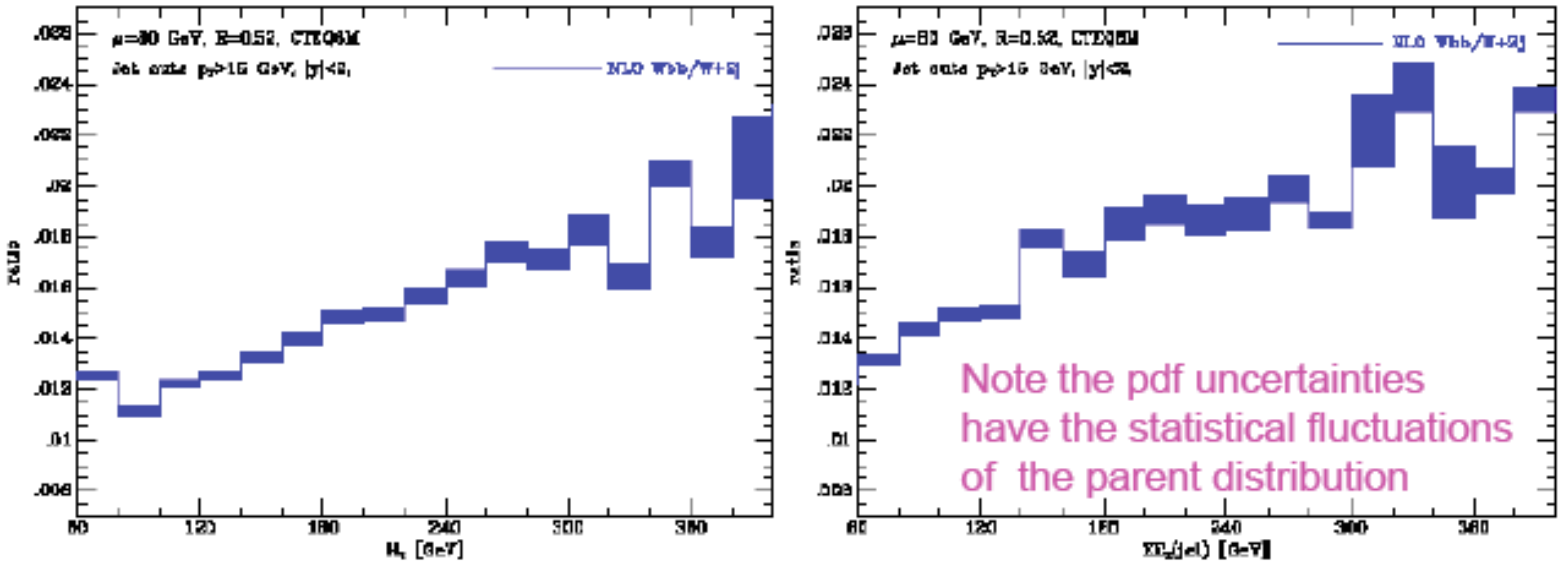
NLO programs can be slow, especially if you have to run 41 pdf's
But if new version of LHAPDF is used, can run full cross section with central pdf and store pdf*pdf luminosity for each event and then re-weight

- Total cross-section uncertainty: Using MCFM, ~~see CDF6849~~

  J. Campbell and J. Huston:hep-ph/0405276->PRD

  $W b\bar{b} \rightarrow 2.5\%\,, \qquad W + 2j \rightarrow 1.5\%.$

- Uncertainty in the $(W b\bar{b}/W + 2$ jet) ratio:



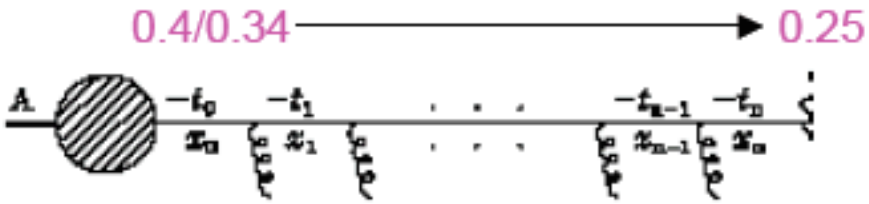
In Version 3 of LHAPDF, all pdf's can be stored in memory at the same time

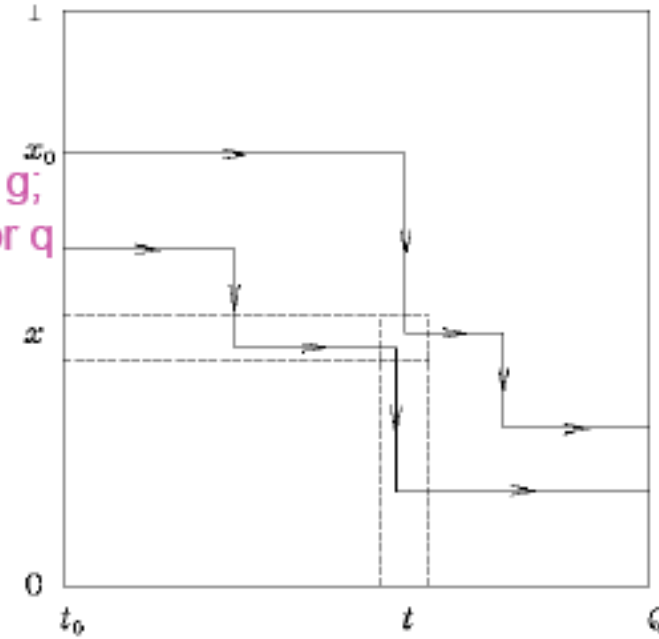
PDF uncertainty for any cross section can be calculated by weights

PDF weight technique with parton showers

- An error may be introduced when using this technique with parton shower Monte Carlos
- The backward evolution in the initial state depends not only on the value of the pdf at a specific x and Q^2 value but also the slope of the pdf in going to higher x and lower Q^2
- In ISR, parton evolves backwards towards higher x and lower Q^2
- Backwards evolution Sudakov factors are weighted by the ratio of pdf's
- So the larger a pdf is at higher x and lower Q^2, the larger is the probability of a gluon emission having occurred

This technique has correct Sudakov only for CTEQ6, not for error pdf's.





0.4 for g;
0.34 for q

0.25 on average

At the Tevatron, for top production, quarks start at about x=0.34 at Q_o and end at x=0.25 at $Q^2=10^4$ GeV^2;
gluons start higher at x=0.4

Uncertainties on Sudakov form factors

Uncertainties of Sudakov form factors

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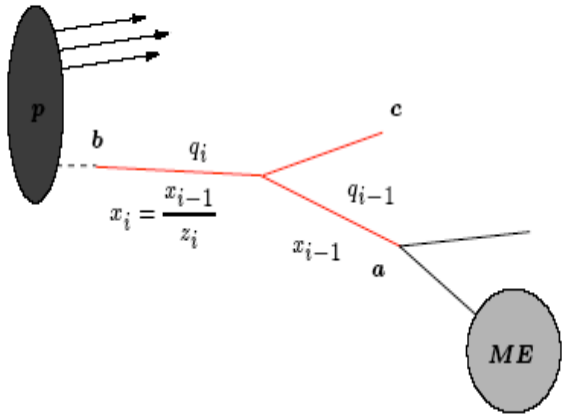
ABSTRACT: We study the uncertainties of Sudakov form factors as the basis for parton shower evolution in Monte Carlo event generators. We discuss the particular cases of systematic uncertainties of parton distribution functions and scale uncertainties.

KEYWORDS: Quantum Chromodynamics, Monte Carlo Event Generator, Parton Shower, Parton Distribution Functions.

See Stefan's talk from Friday afternoon.

Consider only single branching $b \to ac$:



Sudakov decomposition $q_i = \alpha_i p + \beta_i n + q_{\perp i}$. Basis $(p, n)\|$ proton direction. reconstructed from

$$\alpha_i = \frac{\alpha_{i-1}}{z}, \qquad \boldsymbol{q}_{\perp i} = \frac{\boldsymbol{q}_{\perp i-1} - \boldsymbol{p}_{\perp i}}{z_i} .$$

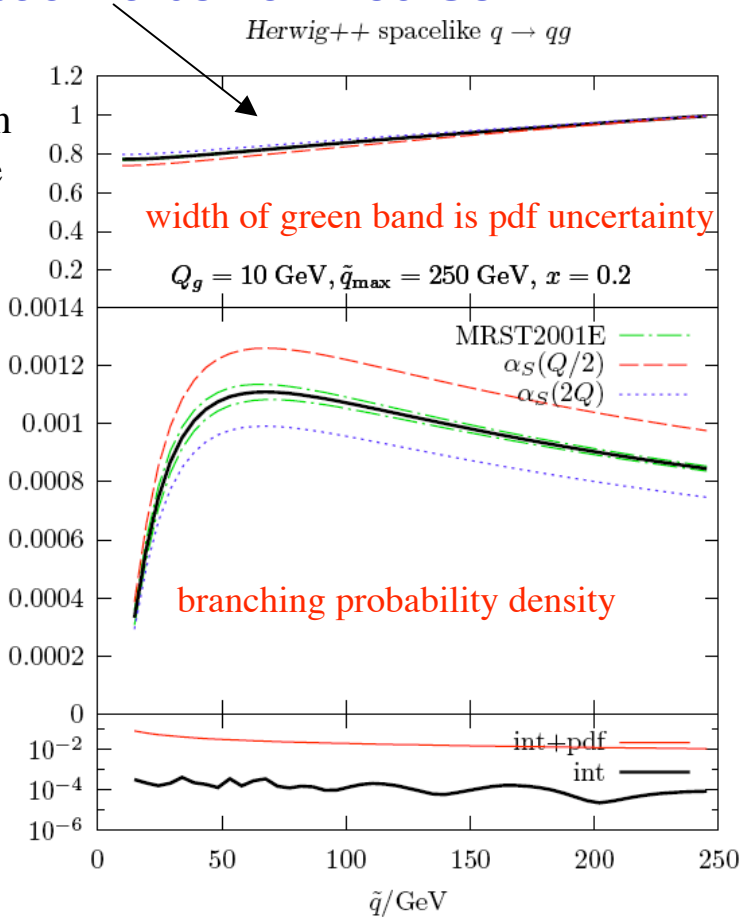
$$\boldsymbol{p}_{\perp i}^2 = (1 - z_i)^2 \tilde{q}_i^2 - z_i Q_g^2 .$$

Q_g closely related to parton shower cutoff.

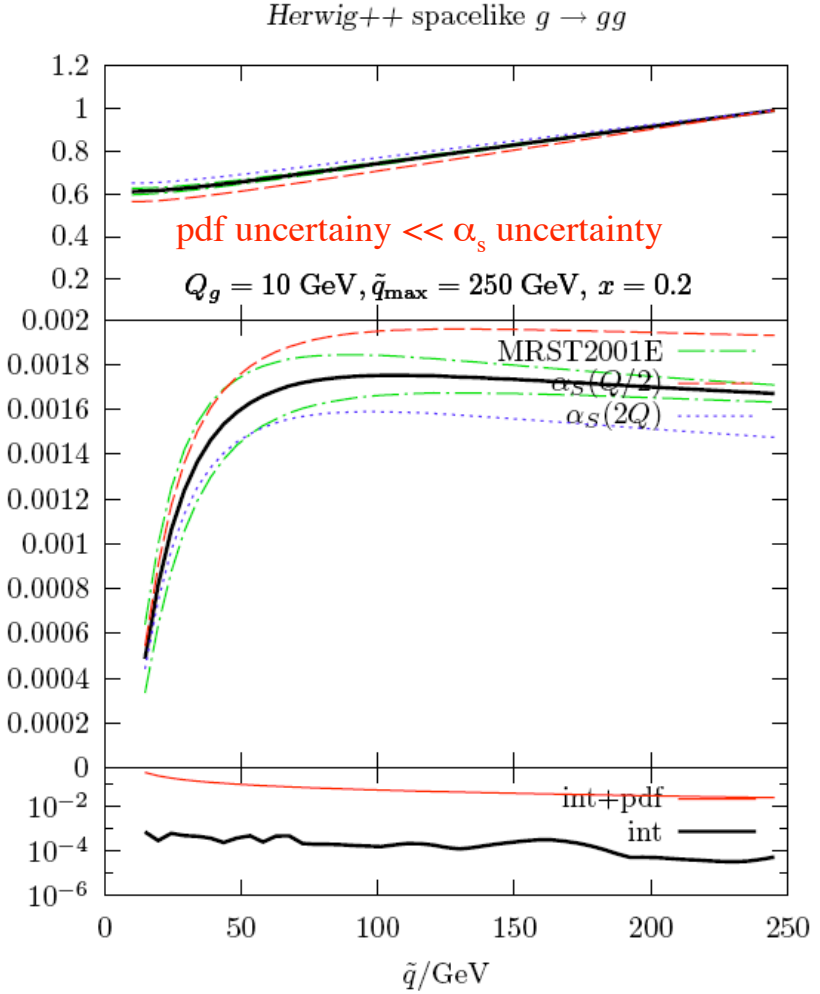
Uncertainties on Sudakov form factors

Probability that a quark at x=0.2 will not emit a gluon of greater than 10 GeV when evolving backwards from 250 GeV

so there's an 80% chance for a quark of x=0.2 to evolve backwards from 250 GeV to 10 GeV **without** emitting a gluon of more than 10 GeV



Gluons like to radiate more than quarks; probability is only 60% for a gluon of x=0.2



PDF uncertainty band (MRST2001E) is very small; pdf weighting technique works.

ME/MC projects

1. W + jets comparisons at the Tevatron->predictions for the LHC

   -NLO->MCFM

   -CKKW

   -Mrenna-Richardson

   -Sherpa

   -backgrounds to WW->H, the "Zeppenfeld plots"

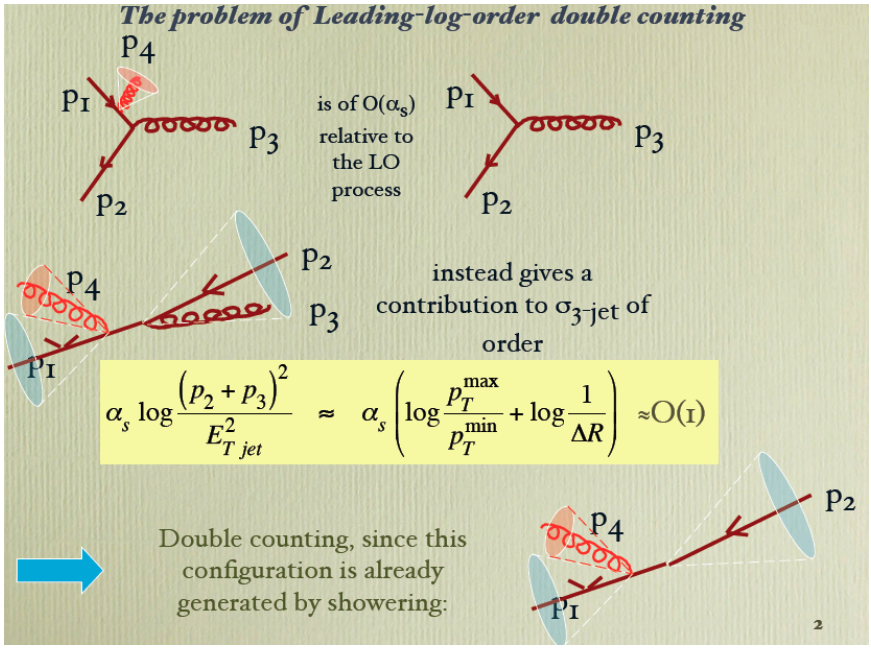
   Michael Begel,John Campbell, Ben Cooper, Joey Huston, Rachid Mazini, Steve Mrenna, Dave Waters, Dieter Zeppenfeld, Marek Zielinski

2. parton shower/resummation

   -predictions for tt, Higgs

   -impact of new parton shower algorithms

   Joey Huston, Steve Mrenna, Peter Skands, Torbjorn Sjostrand

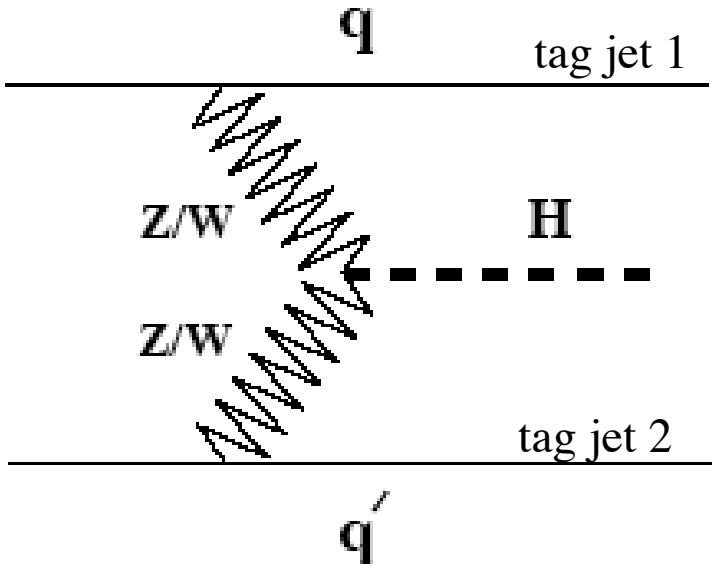


- need to control size of unwelcome logs when interfacing ME and PS
- mlm and CKKW approaches for controlling logs both in use at Tevatron

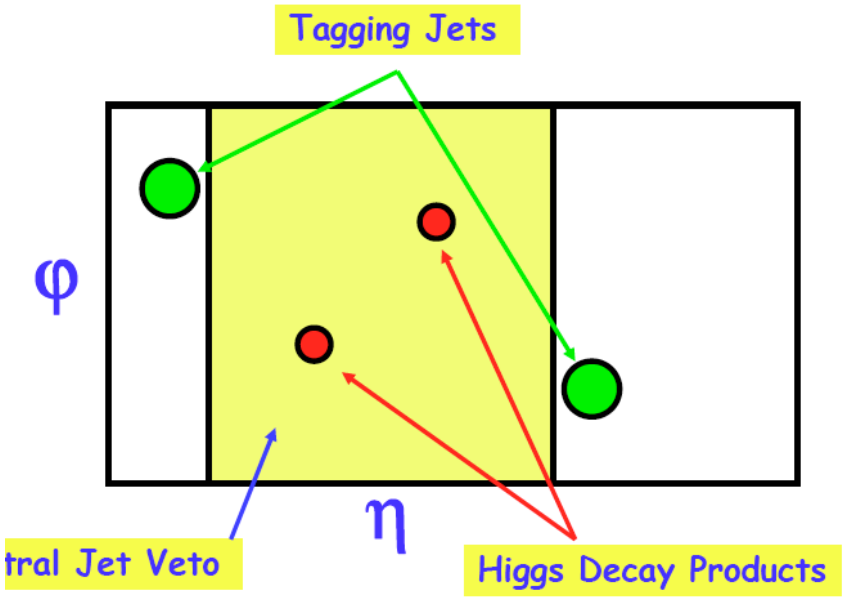
See, for example, talk by Michael Begel on Friday on matching in W+jets/dijet events

WW fusion: the Zeppenfeld plots

- Some of the primary search modes for a Higgs discovery at the LHC proceed through the WW fusion process



- Several different decay modes for Higgs accessible
- Two key features of VBF production:
  - presence of forward-backward tagging jets with large rapidity separation
  - suppression of gluon radiation in central rapidity region between the jets due to color singlet



Backgrounds

- There are sizeable backgrounds to this production process due to W + 2 jets/top production
- See, for example, talk of Dieter Zeppenfeld in first meeting of TeV4LHC; my talk from Dec TeV4LHC WG meeting
- At the Tevatron, Higgs production not accessible through this process, but we can try to understand level of background
  - and in particular effect of a central jet veto
- MC plots here; data comparisions blessed for Moriond

From Bruce Mellado's talk on Thursday

- W/Z production + jets, jet veto (Zeppenfeld plots)
  - Central point in this Tevatron/LHC connection

Background studies

- For W+>= 2 jets at the Tevatron
  - look at $|\eta_1-\eta_2|$ as a function of p_T^{min}
  - compare to MCFM, LO and NLO; ALPGEN/MADGRAPH+ Herwig/Pythia (mlm matching and CKKW)
    - CKKW generated by Steve Mrenna using Madgraph+Pythia
- For W+>=3 jets
  - η_3^* distribution as a function of p_T^{min} and $|\eta_1-\eta_2|$
    - $\eta_3^*=\eta_3-(\eta_1+\eta_2)/2$
  - 3 jet fraction as a function of p_T^{jet3}

Dieter Zeppenfeld; talk at TeV4LHC

Expected (LO) cross sections for 2,3 jets in $W^\pm$ production; B(W → eν, μν) included

$p_{Tj} > 15$ GeV, $|\eta_j| < 3$

	W+2j	W+3j	σ_3/σ_2
$\|\eta_1-\eta_2\|>2$	15 pb	3 pb	19 %
$p_T^{tag}>30$GeV			
$\mu_R = m_W$	3.2 pb	1.4 pb	44 %
$\mu_R = p_{Tj}$	4.2 pb	2.6 pb	62 %
$\|\eta_1-\eta_2\|>3$	0.8 pb	0.37 pb	47 %

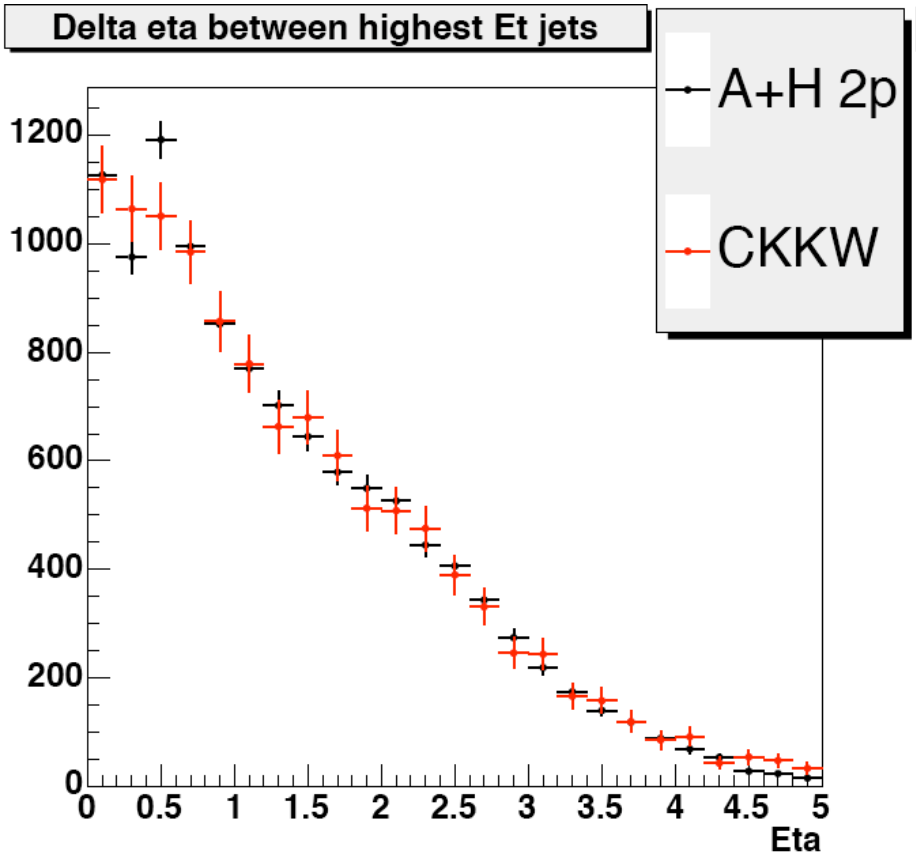
- No NLO calculation for W+3j available → substantial scale dependence
- 3 jet fraction is large → fixed order perturbation theory insufficient

More reliable predictions from parton shower programs?

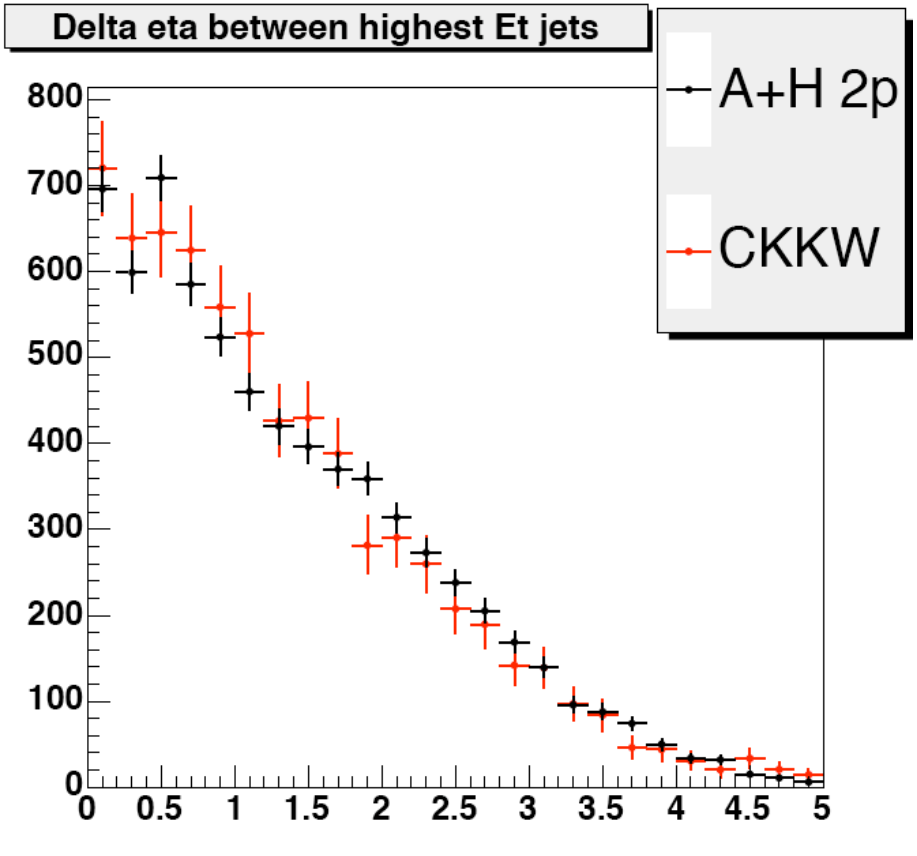
large variation on impact of veto

Δη of tag jet plots: CDF MC

E_T of tag jets > 15 GeV/c



E_T of tag jets > 20 GeV/c



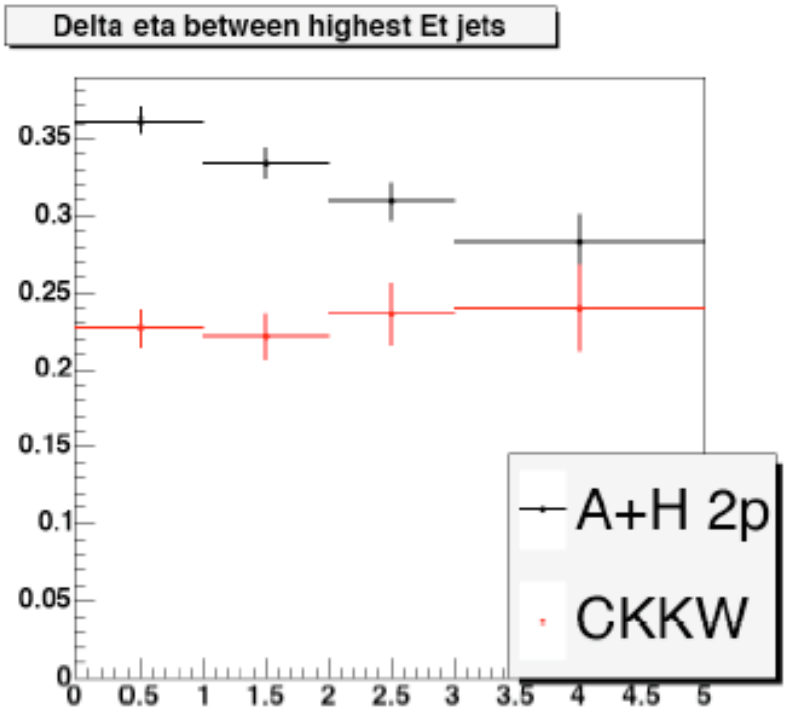
Both A+H and CKKW seem to describe the data reasonably well.

Brief summary of result

- There's a high probability in extra central jets in W+2 jets at the Tevatron
  - good news for WW fusion searches
  - Dieter is happy

  - CKKW describes data best
  - data comparisons will be blessed for Moriond

Tag jets > 15 GeV/c; 3rd jet > 8 GeV/c



fraction of events with >=2 jets that have **only** 2 jets, i.e. ~75% of events have 1 or more extra jets

UE/hadronization topics

1. UE tunes for Tevatron

   ->predictions for LHC

   -understanding color connections and their apparent promiscuity

   -Pythia 6.3

   -Jimmy

   Rick Field, Peter Skands

2. hadronization corrections for NLO processes
3. ISR/UE corrections->subtractions for NLO

   Rick Field, Joey Huston

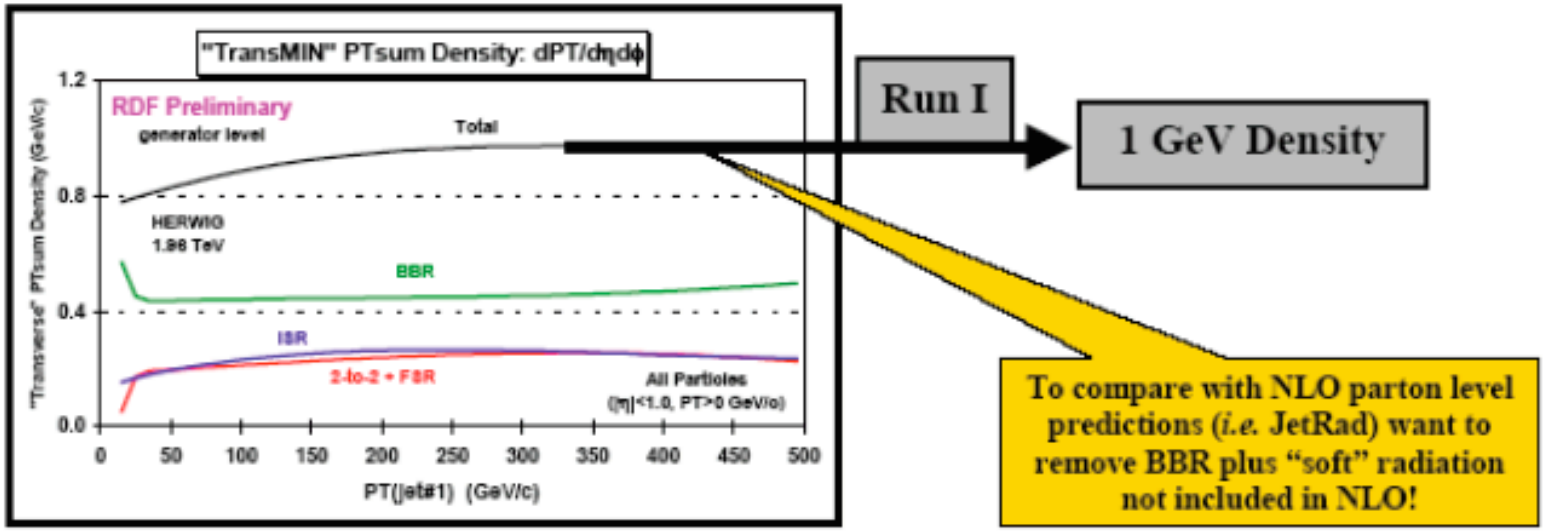
4. understanding high interaction multiplicity environment

- To first order, hadronization corrections are a constant and of order of 1 GeV/c for reasonably high E_T for a cone of 0.7 using Herwig
  - should be checked for other cone sizes, and with other Monte Carlos, i.e. Pythia
  - should be checked for lower values of E_T
  - and we should make a more detailed comparison of parton level jet shape to that from Monte Carlo, data

Subtractions for NLO

Would it be useful to define DPS+ISR in which the hardest gluon is removed (an analog of NLO) and examine how much energy is contributed to jets and to max and min regions? Perhaps with the new version of Pythia where DPS+ISR are treated in a more unified manner? Also with the new version of Herwig including Jimmy.

HERWIG: "MIN Transverse" PTsum Density



More info on project results on the webpage TeV4LHC

- Goals of QCD working group
- Steve Mrenna's summary talk at Sept meeting
- Seminar on TeV4LHC and HERALHC given by Joey Huston at MSU

You're all wondering, How can I enlist?

- Four listserver mailing groups have been set up:

  tev4lhc-qcd
  tev4lhc-higgs
  tev4lhc-topew
  tev4lhc-landscape

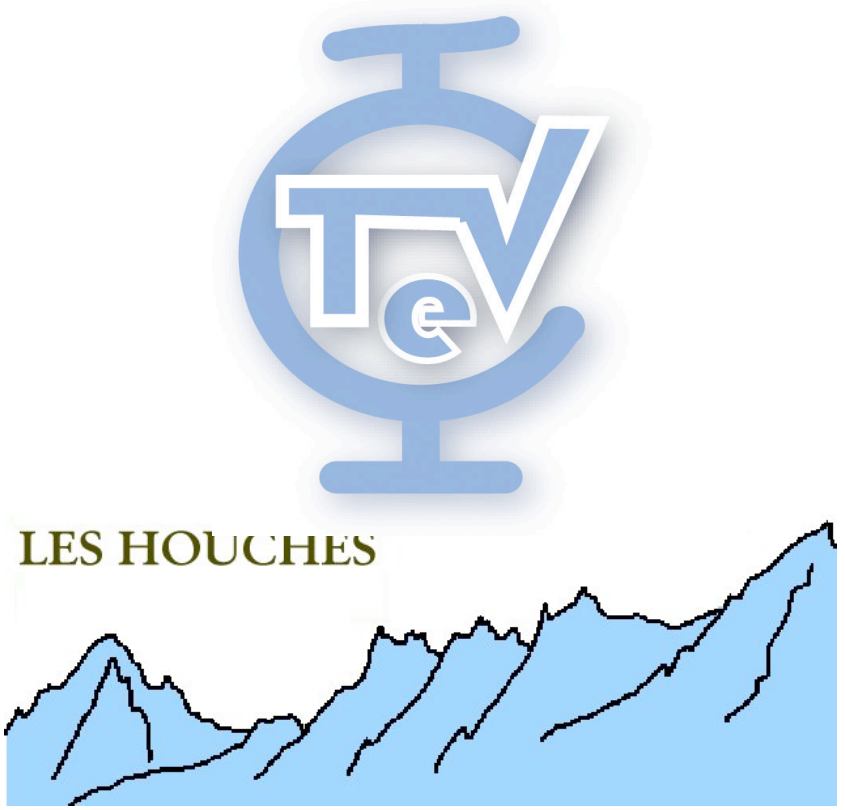
- If you would like to subscribe to the working groups, here are the instructions:
  - To subscribe to a mailing list called MYLIST

    1. Send an e-mail message to listserv@fnal.gov
    2. Leave the subject line blank
    3. Type "SUBSCRIBE MYLIST FIRSTNAME LASTNAME" (without the quotation marks) in the body of your message.

Another workshop

TeV4LHC

- Physics at TeV Colliders
  - From 800 pb^{-1} at the Tevatron to 30 fb^{-1} at the LHC
  - May 2-20
    - right after CERN meeting of TeV4LHC
- 2 main working groups
  - SM and Higgs
  - BSM and Higgs modeling



plan is to continue work from TeV4LHC
one example is inclusion of jet production in MC@NLO