CKKW studies and other news

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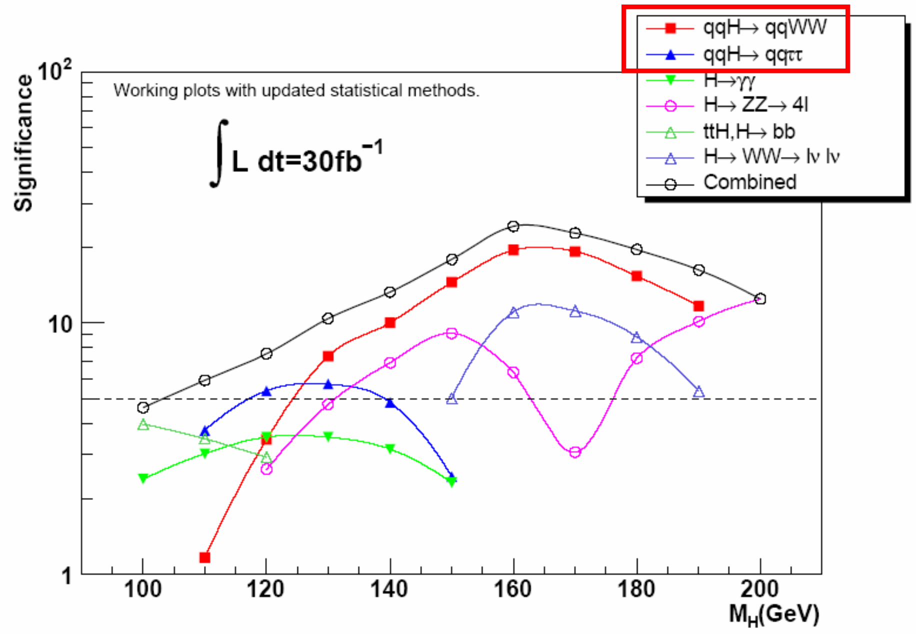
(with help from Ben Cooper and Bruce Mellado)

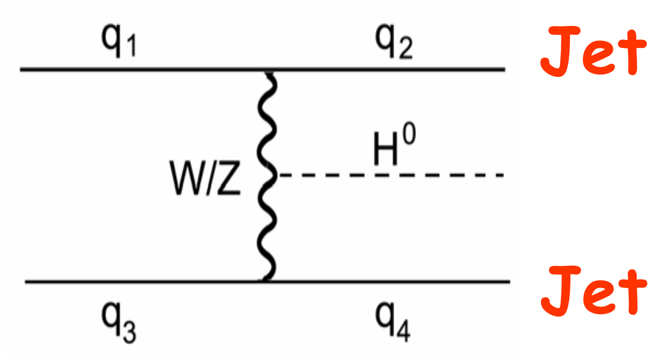
Vector boson fusion

- Vector boson fusion production of a low mass Higgs is one of the most promising production channels at the LHC
  - see Michael Duehrssen's talk from this morning

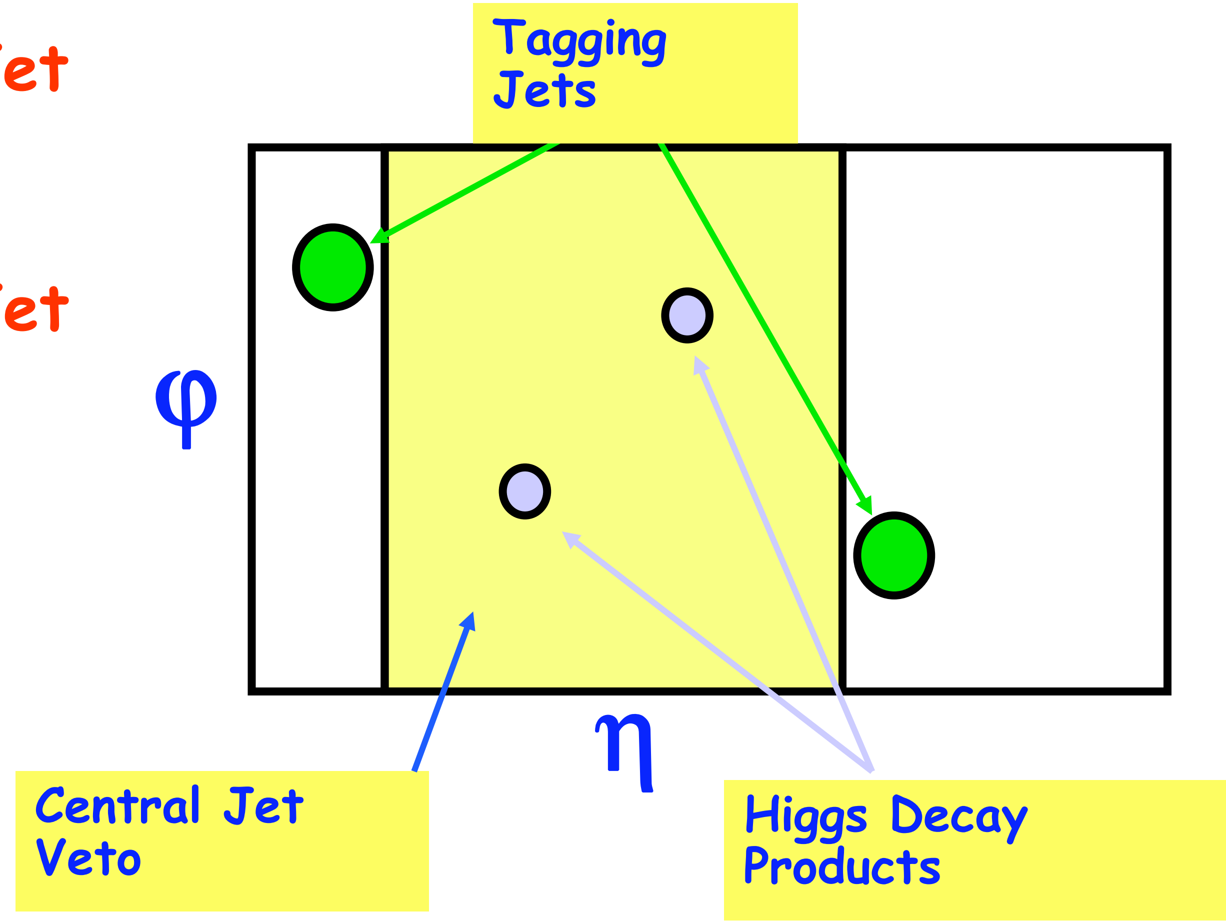


SM Higgs$\rightarrow\tau\tau$ + 2jets

- Look for a Higgs decaying centrally into a τ pair, forward-backward tagging jets and no central jets



$$\eta_{J1} \cdot \eta_{J2} < 0$$
$$\Delta\eta_{JJ} > 3.5 \div 4$$
$$M_{JJ} > 500 \div 700\mathrm{GeV}$$
c.j.v.



Opening meeting

- This discovery channel has a potentially large background from Z + 2 jets where the Z decays to a τ pair
- Z + 2 jets widely separated in rapidity is likely to have additional jets radiated in the central region
- A central jet veto will help to reduce this background while leaving most of the VBF Higgs signal
- Dieter gave a talk at the TeV4LHC opening meeting (in transparency pen!) in which he pointed out that there was a great deal of variation in the (LO) predictions for 3rd jet emission in W/Z + 2 jet events
  - if probability too small could remove the effectiveness of 3rd jet veto

Dieter Zeppenfeld; talk at TeV4LHC

Expected (LO) cross sections for 2,3 jets in $W^\pm$ production; $B(W \to e\nu, \mu\nu)$ included

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

	W+2j	W+3j	σ_3/σ_2
$\lvert\eta_1-\eta_2\rvert > 2$	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 %
$\lvert\eta_1-\eta_2\rvert > 3$	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 ?

Tevatron studies

- We can't help with the VBF Higgs discovery channel at the Tevatron but we can look at the rates for central jet emission in W/Z + jet(s) events
- Cross section larger for W + jets so that is primary investigation
- Will compare measured cross sections to LO +PS predictions and to fixed order (LO and NLO) predictions from MCFM
- In particular, are interested in comparing to CKKW cross sections generated by Steve Mrenna
- As usual, data is not blessed yet, so that can't be shown to this audience, but will be included in final TeV4LHC writeup

CKKW/MCFM

- CKKW procedure combines best of exact (LO) matrix element and parton shower description of multijet events
- Currently implemented in Sherpa Monte Carlo and approximately implemented in ALPGEN (mlm procedure)
- Steve Mrenna generated a sample of W^+ + n jet events at the Tevatron using Madgraph + Pythia with the CKKW formalism and that's what we'll use
  - hep-ph/0312274
- MCFM calculates cross sections for W/Z/H(VBF) + 2 jets at NLO and the 3 jet cross section at LO

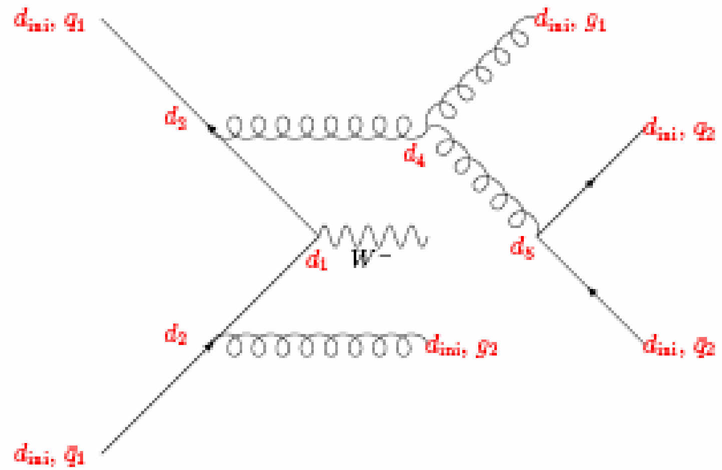


Figure 2: Example of the clustering of a W + jets event. The values of the k_T-parameter at the nodes are such that $d_{ini} < d_5 < d_4 < d_3 < d_2 < d_1$. The parton showers of the incoming quark q_1 and antiquark $\bar{q}_1$ start at the scale d_1 at which they annihilated. The parton showers of the quarks q_2 and $\bar{q}_2$ start at the scale d_4 at which the virtual gluon they came from was produced, assuming that this gluon is softer than the gluon, g_1. The parton shower of the gluon g_2 starts at the scale d_2, and the shower of gluon g_1 starts at the scale d_3 at which the gluon which branched to produce it was produced.

Matching scale

- The CKKW procedure chooses a scale at which to separate the parton shower description and the matrix element description
- The variation of predictions as the scale is changed is an indication of the uncertainty inherent in the procedure

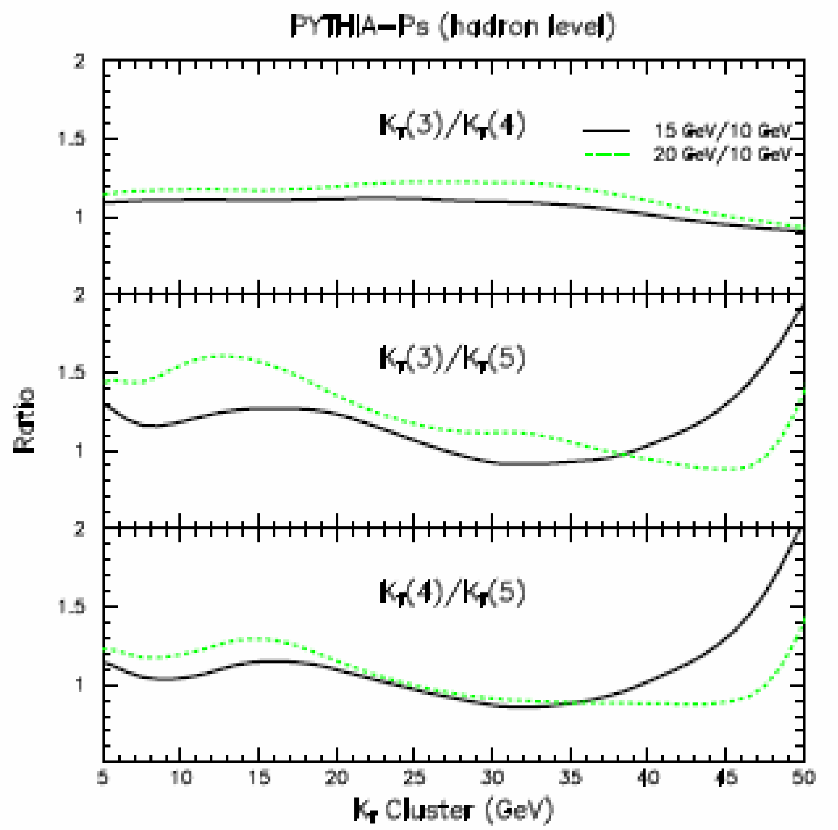
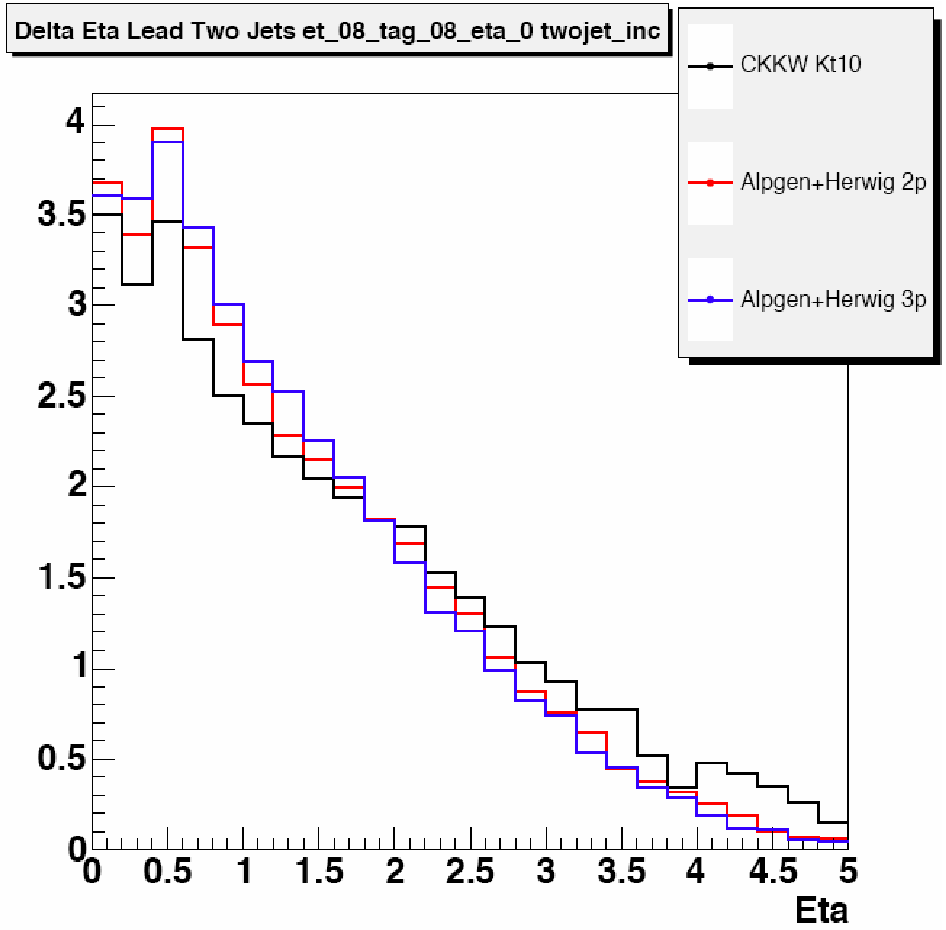


Figure 19: Comparison of the ratio of k_T cluster distributions in Fig. 18 for the same matching scales.

$\Delta\eta$ of tag jet plots

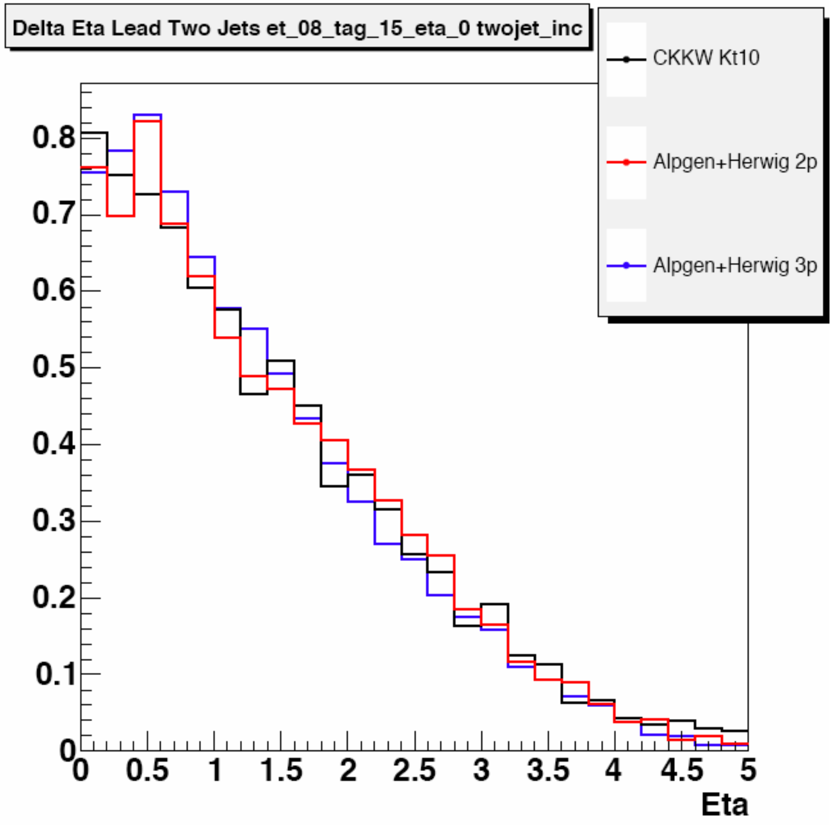
- Look at η difference between tagging jets
- Compare to Alpgen W + 2/3 partons) interfaced to Herwig for additional parton showering and to CKKW sample (generated with Madgraph interfaced to Pythia)
- 3 different E_T cuts on tagging jets

E_T of tag jets > 8 GeV/c

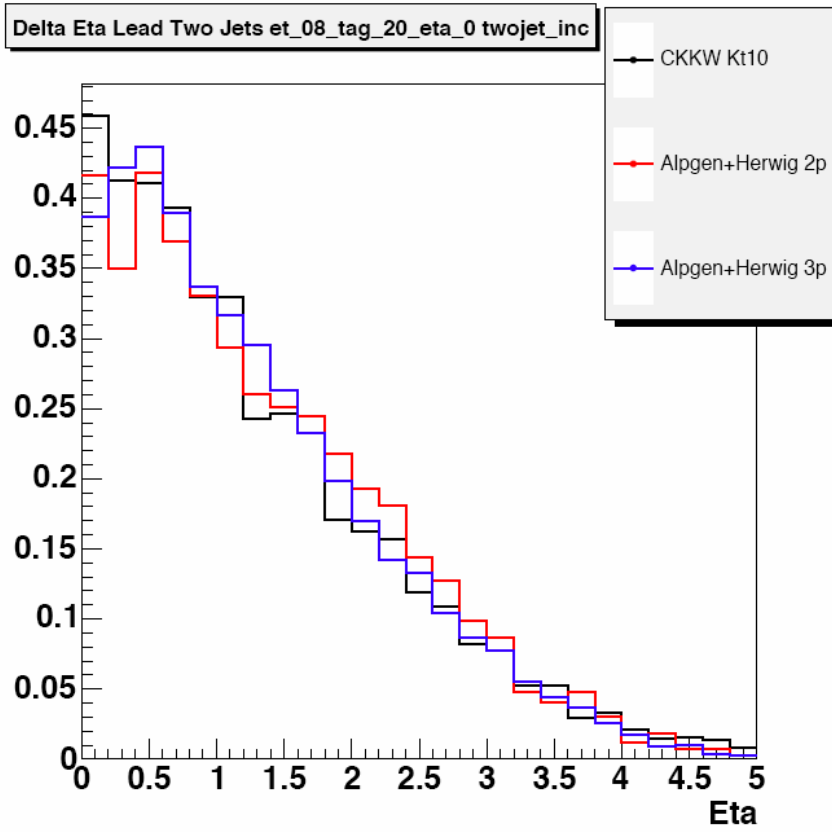


Δη of tag jet plots

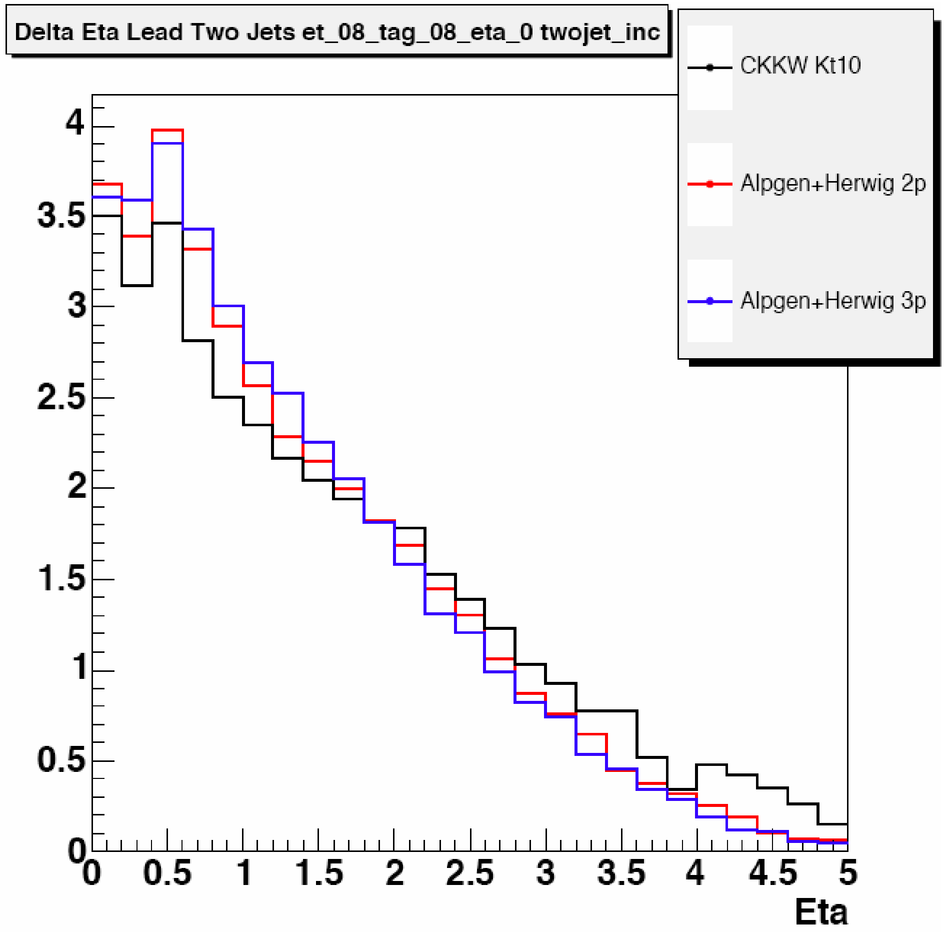
E_T of tag jets > 15 GeV/c



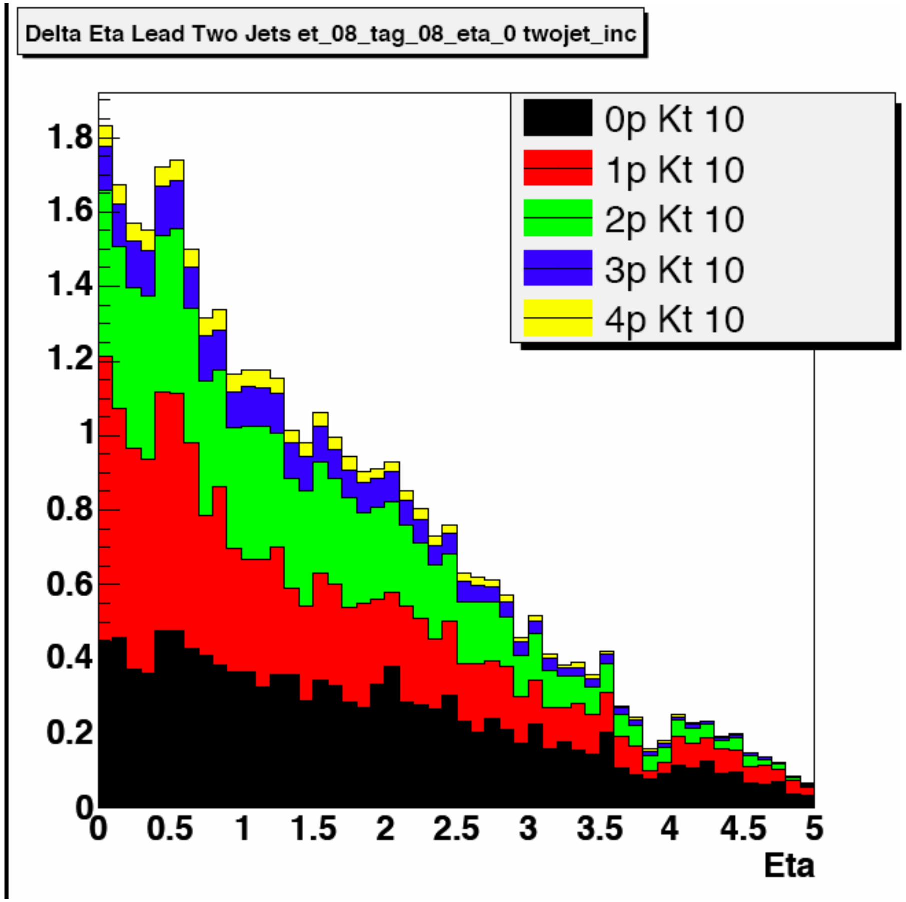
E_T of tag jets > 20 GeV/c



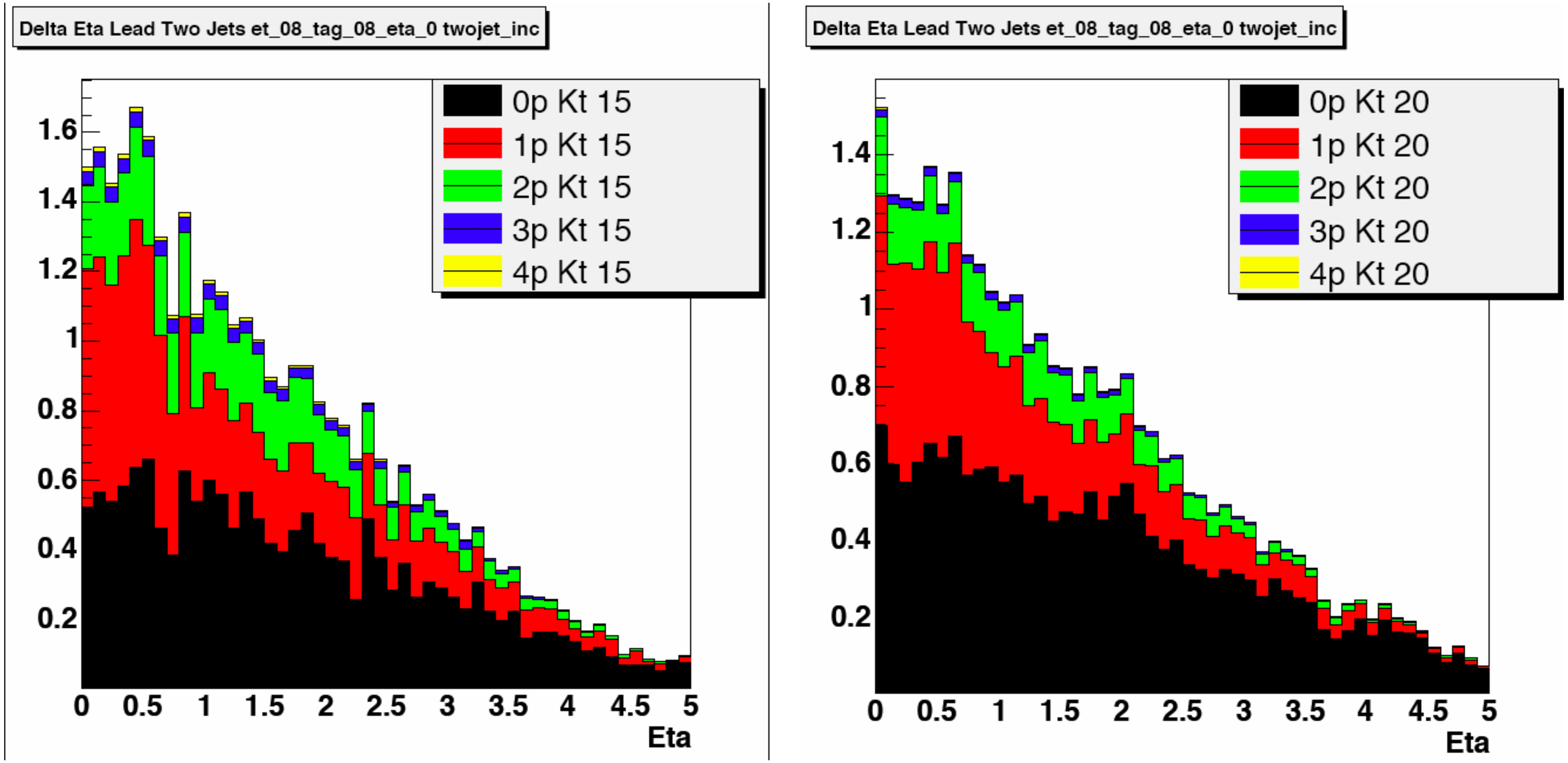
E_T of tag jets > 8 GeV/c



- CKKW decomposition



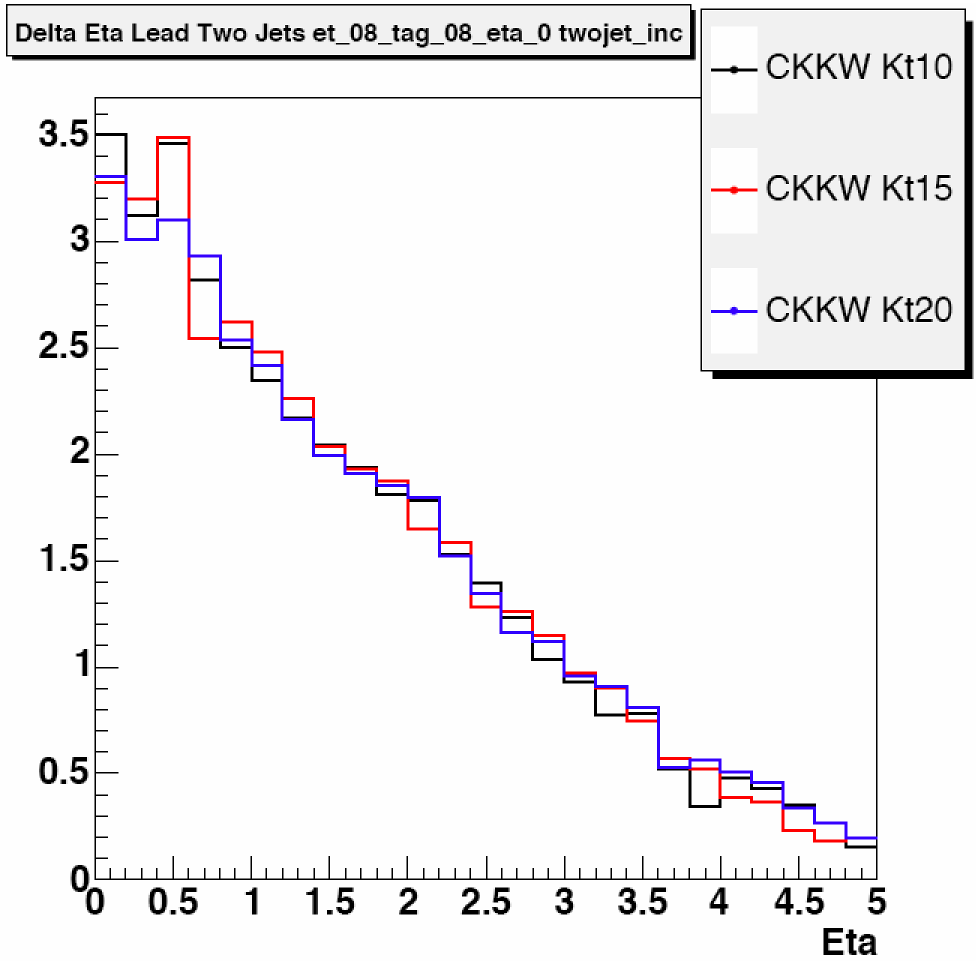
Matching scales



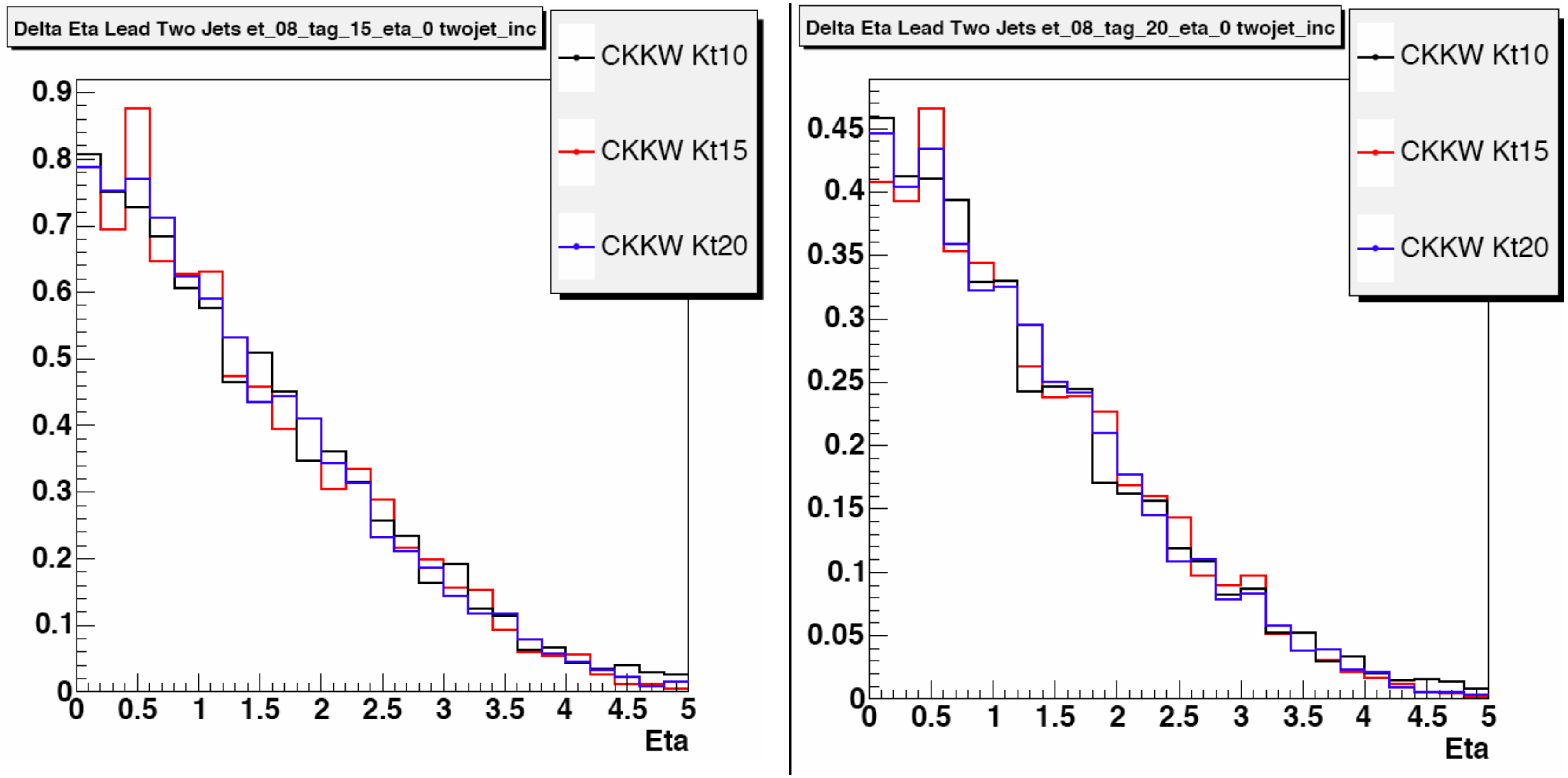
Larger matching scales leads to more production from parton shower

Matching scales

- Shape of $\Delta\eta$ distribution stable with respect to choice of matching scale

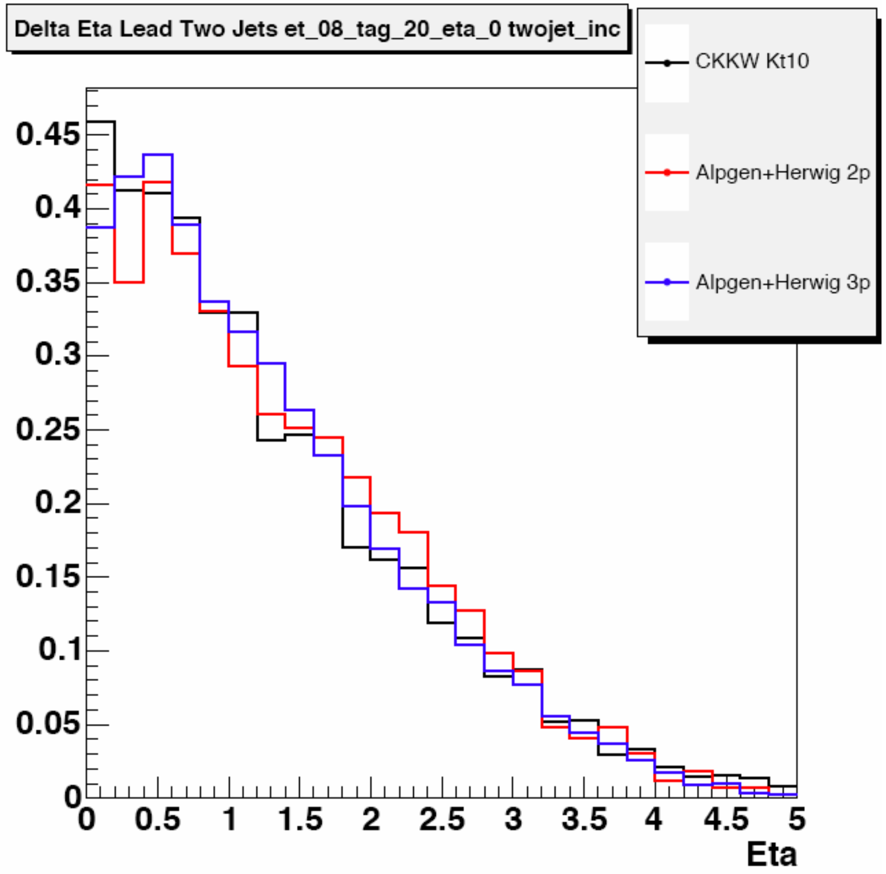


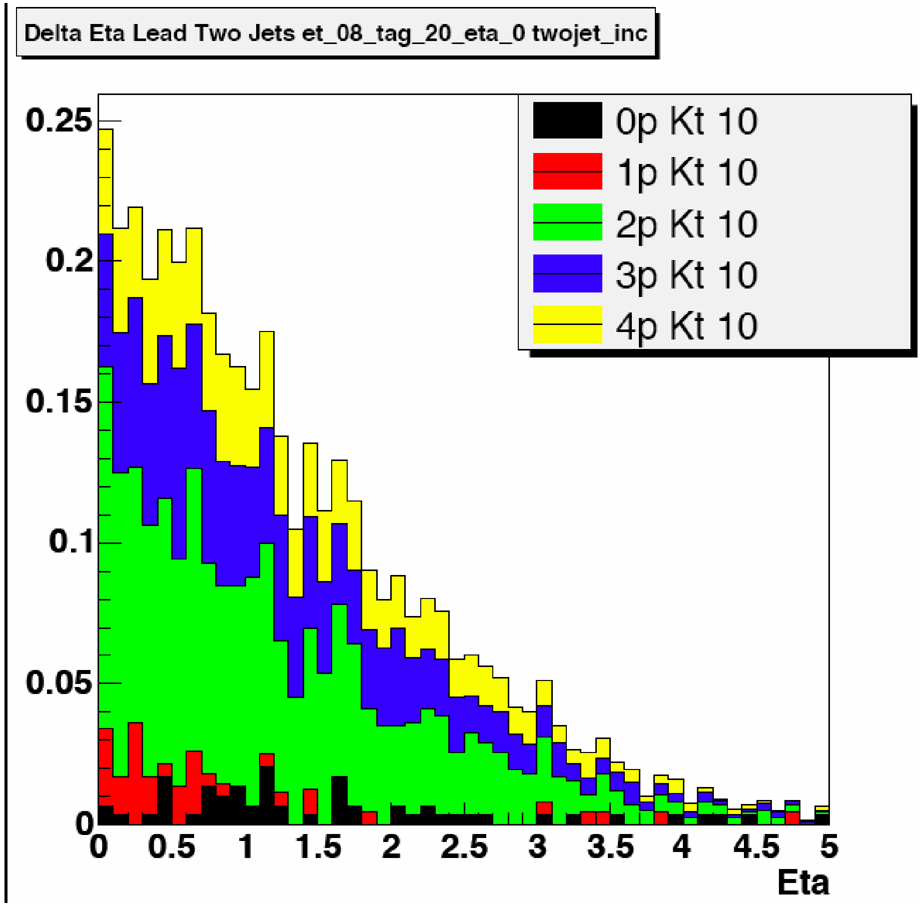
E_T of tag jets > 15 + 20 GeV/c



E_T of tag jets > 20 GeV/c

- CKKW decomposition

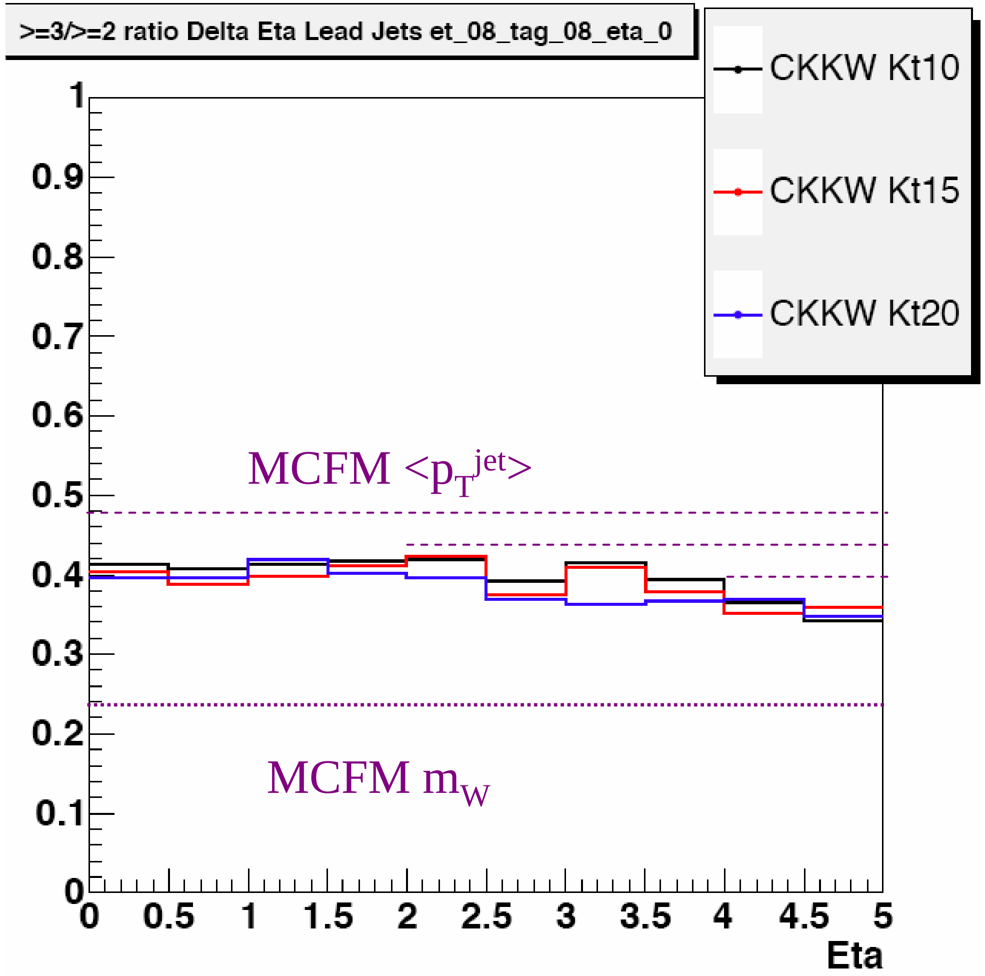




For low E_T tagging jets, W + 0 p relatively important; 2 p required for higher E_T

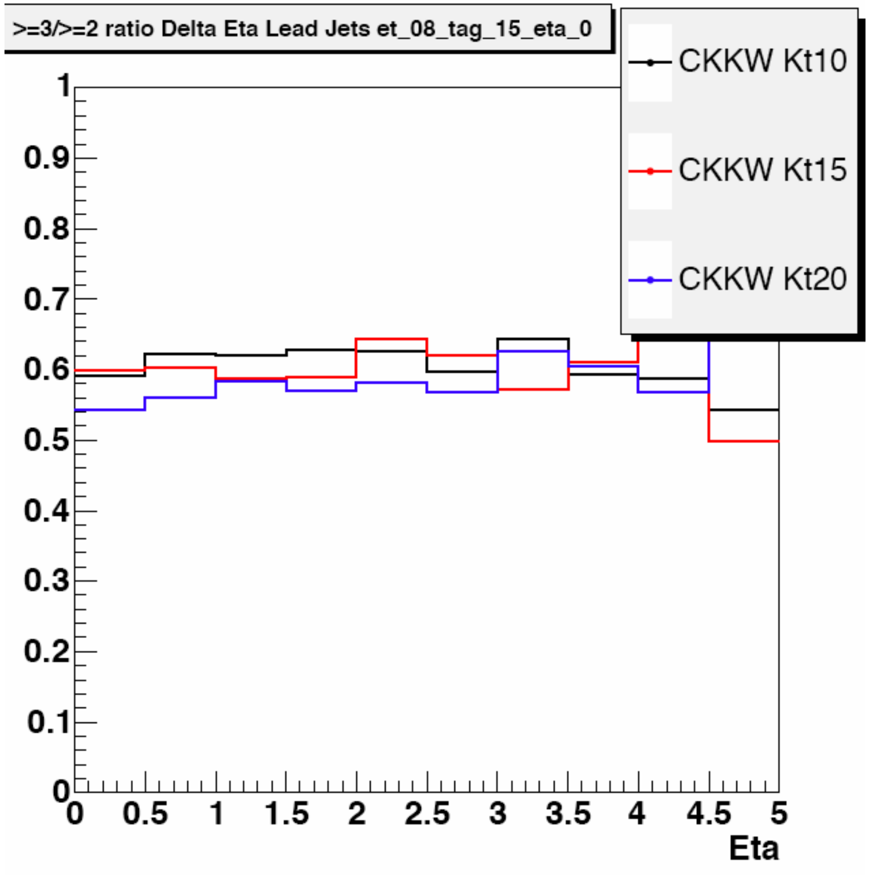
CKKW matching variation

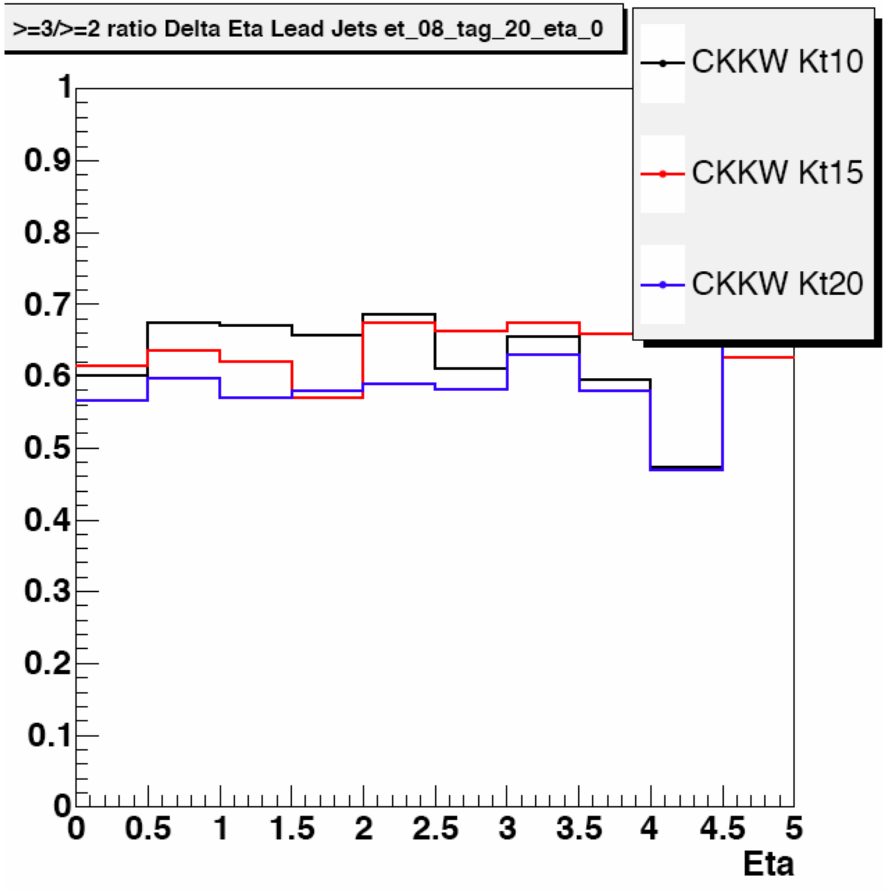
- Look at probability for 3rd jet to be emitted as a function of the rapidity separation of the tagging jets
- Relatively flat probability, stable with CKKW scale
- Bracketed by two predictions for MCFM using m_W and $<p_T^{jet}>$ as scales



CKKW matching variation

- Increase cut on tagging jet to 15/20 GeV/c
- Probability of jet emission increases

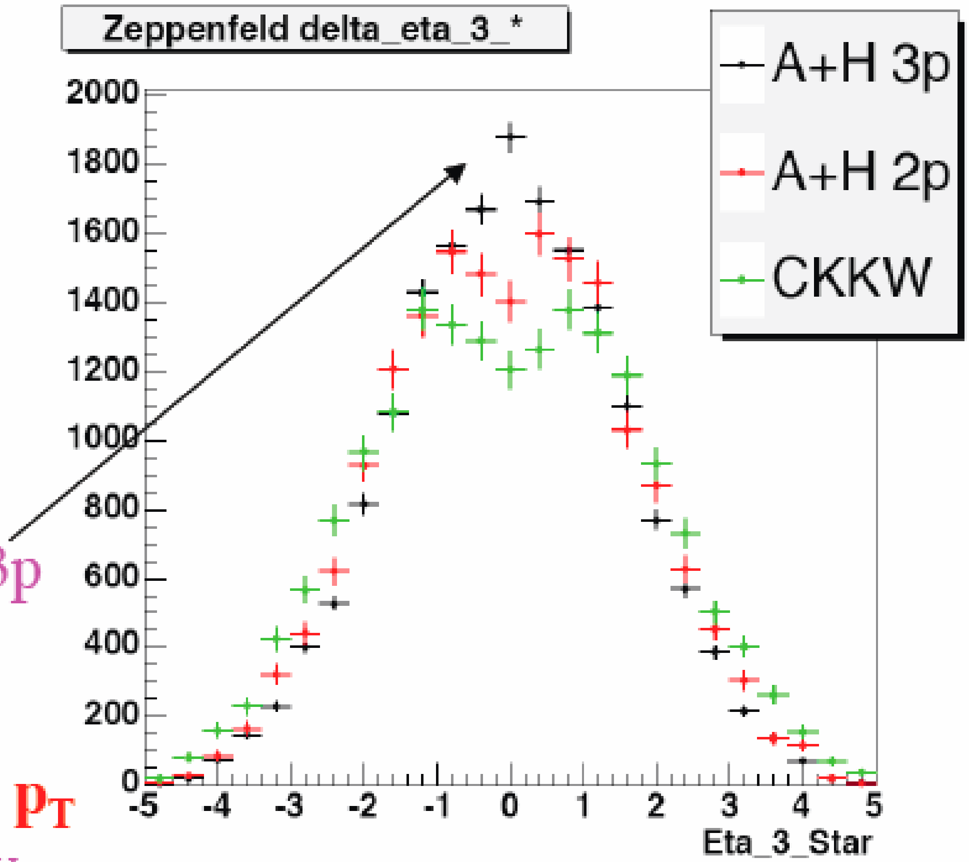




η_3* for $\Delta\eta$ > 1

- Look at η_3* distribution (as defined by Dieter in his talk) for 3 different tagging jet cuts and for 3 different tagging jet $\Delta\eta$ cuts

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



note peak for A+H 3p

…or dip for other distributions

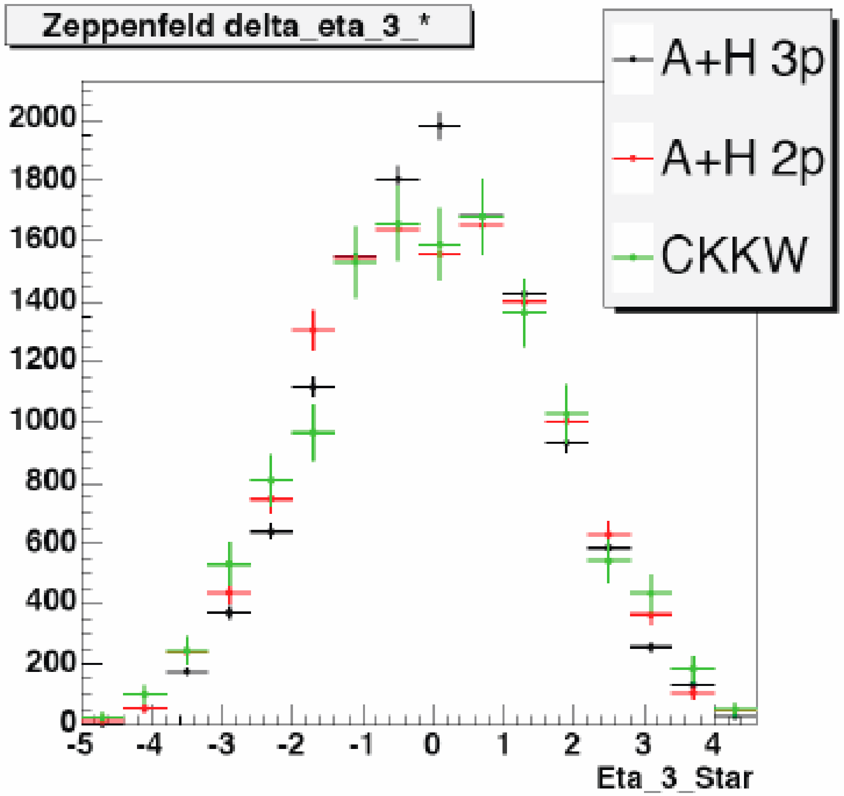
data has dip **for low** p_T

CKKW has Sudakov suppression where ME does not

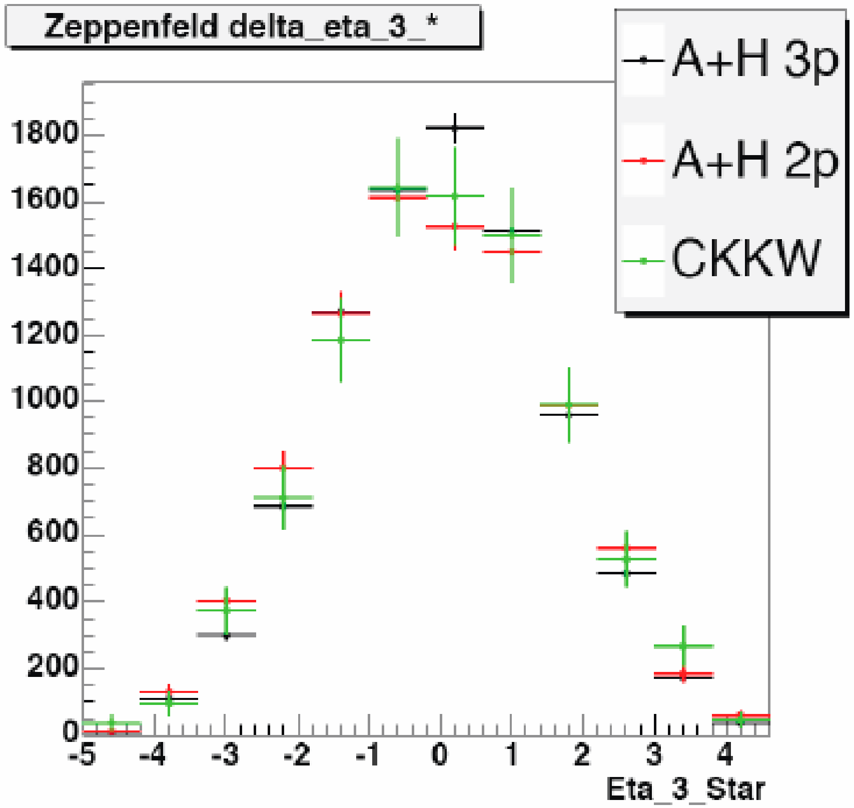
$$\eta_3^* = \eta_3 - \left(\frac{\eta_1 + \eta_2}{2}\right)$$

η_3* for $\Delta\eta$ > 1

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



Tag jets > 20 GeV/c; 3rd jet > 8 GeV/c

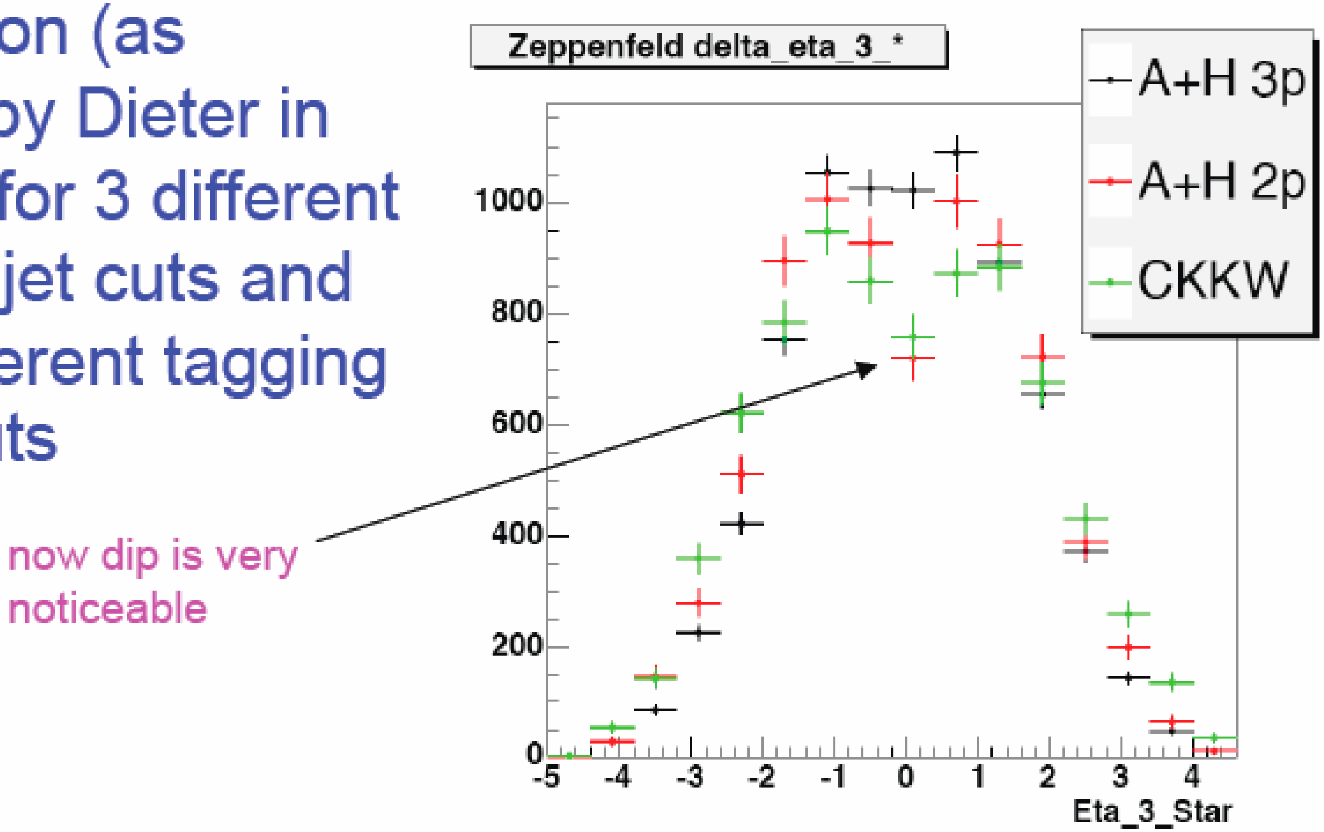


Dip fills in as tag jet E_T increases

η_3* for $\Delta\eta$ > 2

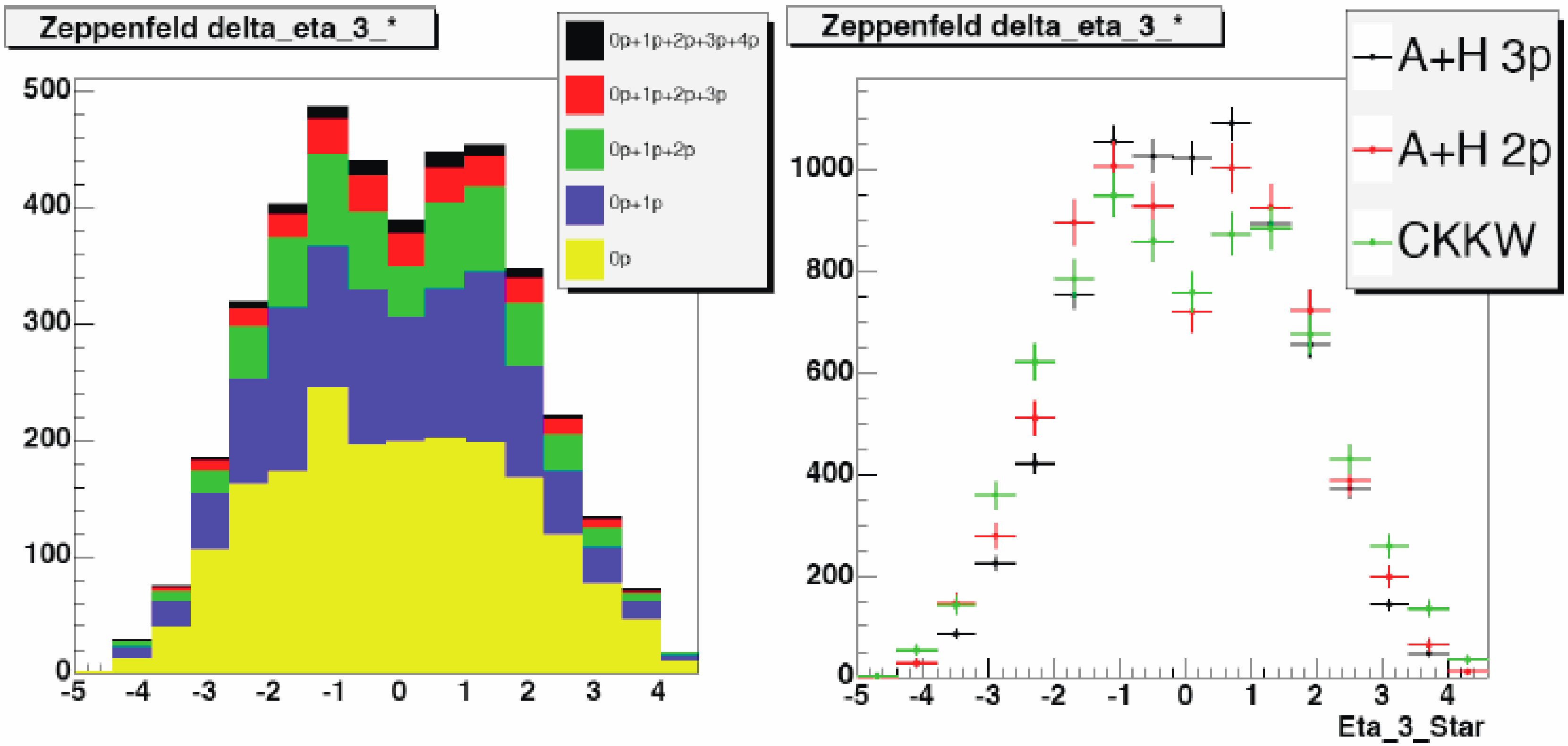
- Look at η_3* distribution (as defined by Dieter in his talk) for 3 different tagging jet cuts and for 3 different tagging jet $\Delta\eta$ cuts

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



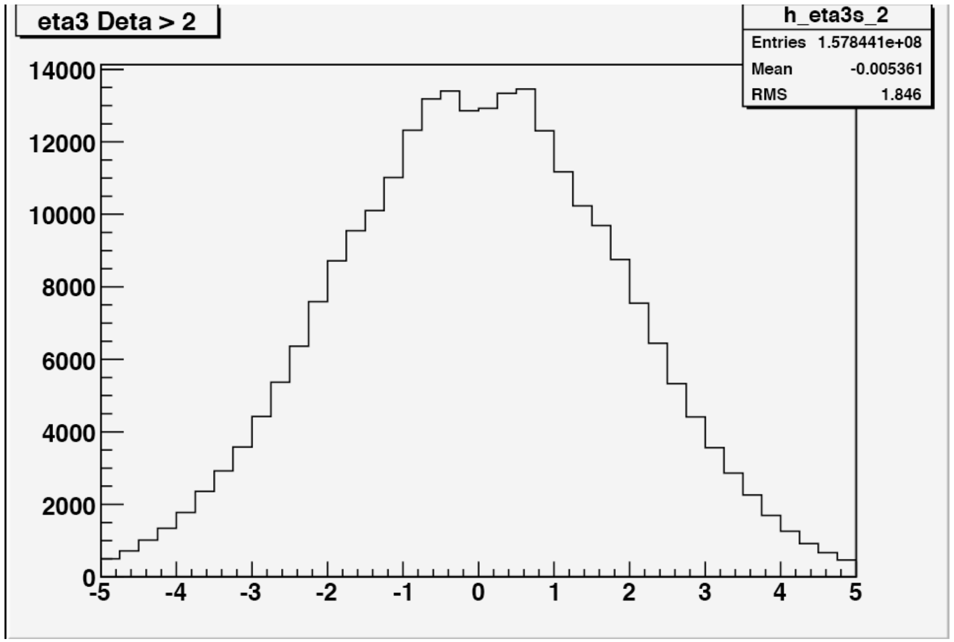
η_3* for $\Delta\eta > 2$

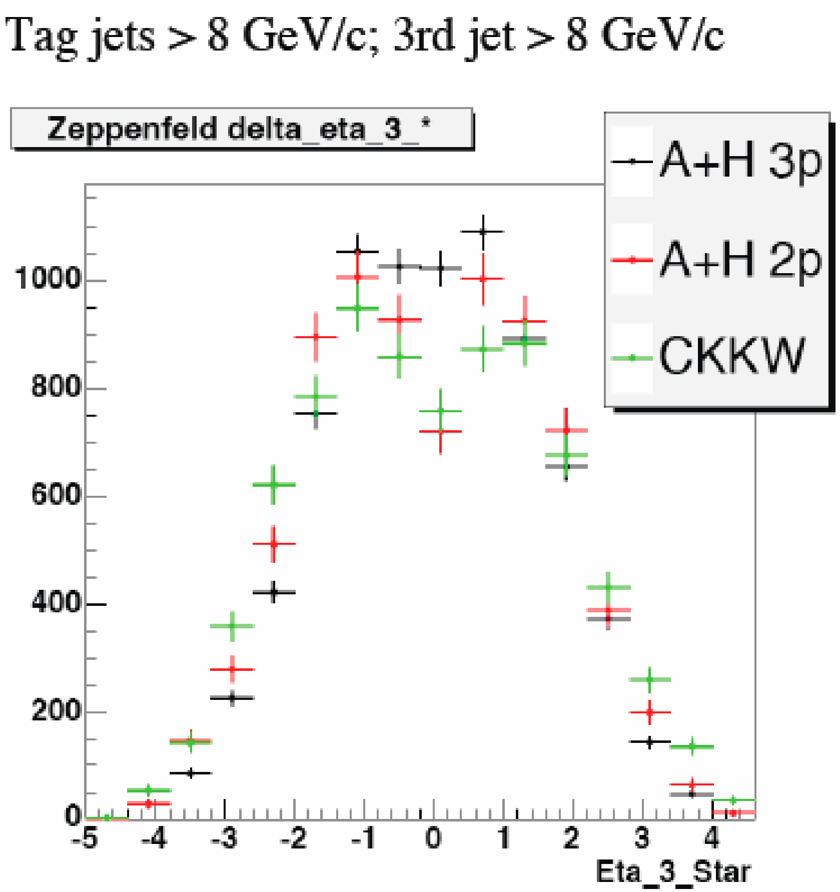
Tag jets > 8 GeV/c; 3rd jet > 8 GeV/c



η_3^* for $\Delta\eta > 2$

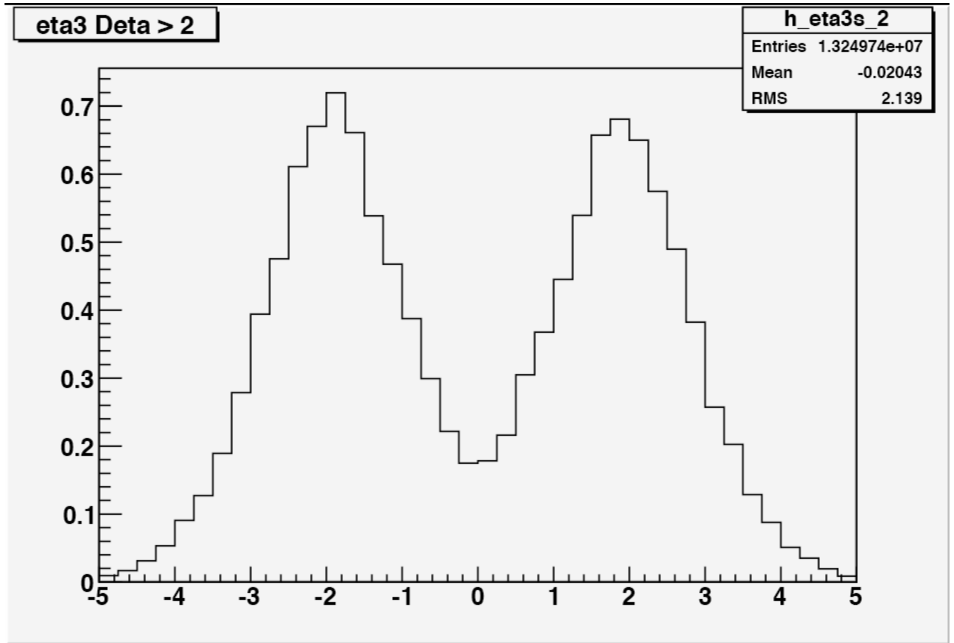
- Dip is also absent for MCFM (LO only since 3 jets in final state)

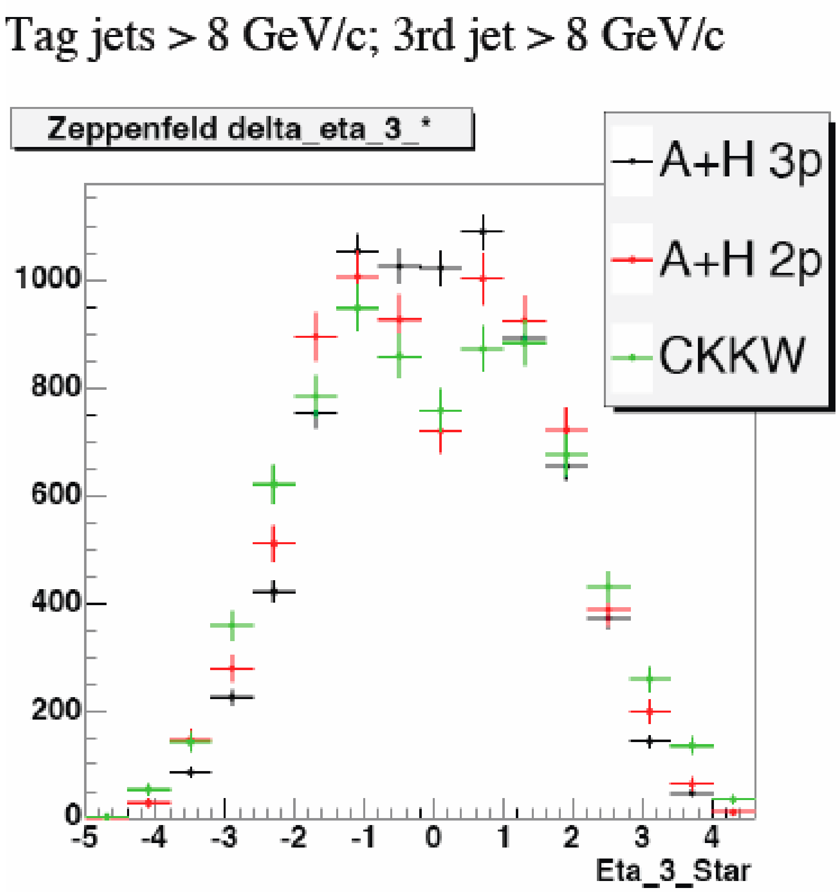




η_3^* for $\Delta\eta > 2$

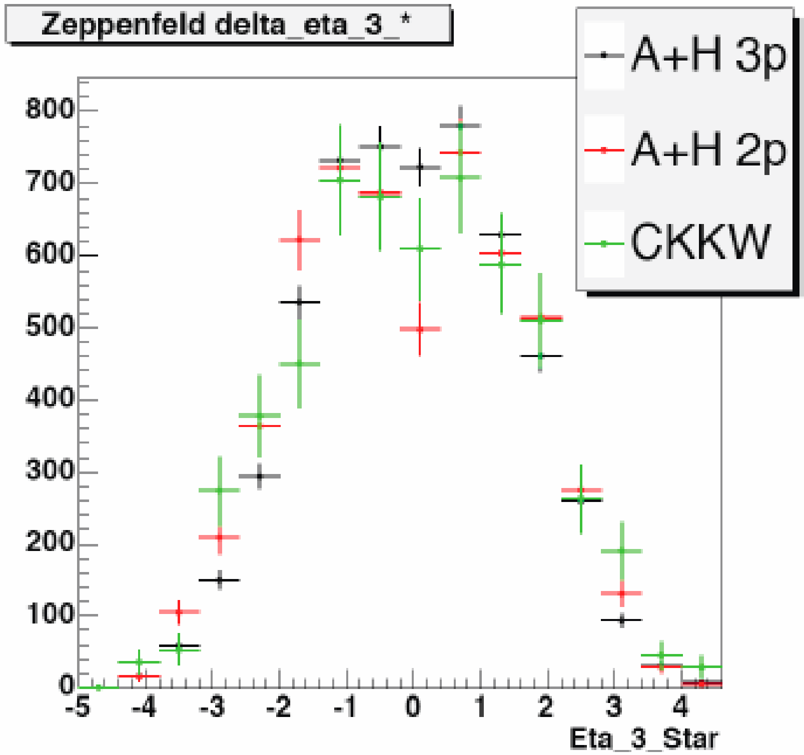
- For comparison, below is distribution for VBF production of Higgs at the Tevatron



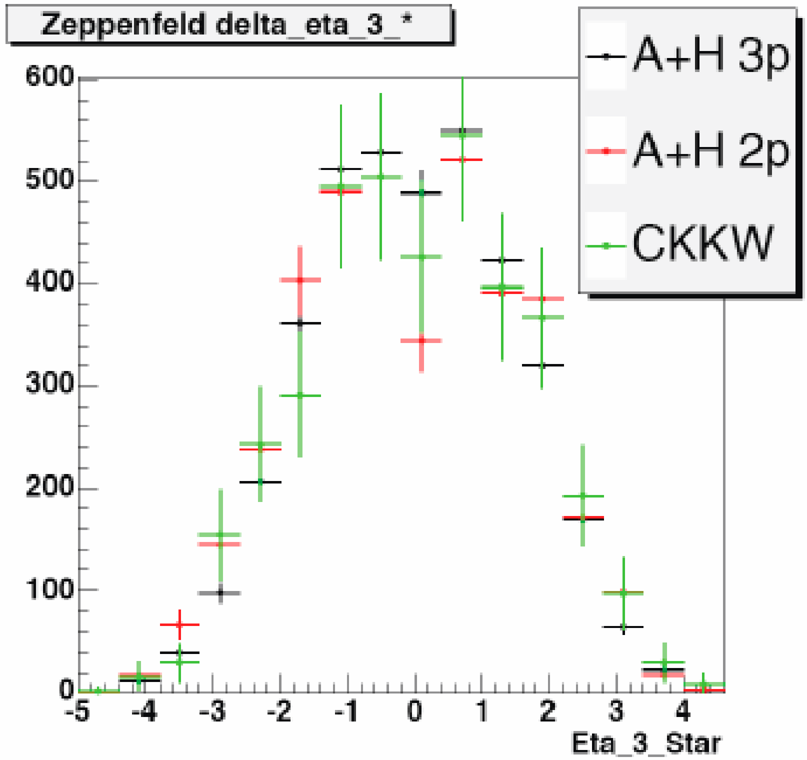


η_3* for $\Delta\eta > 2$

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

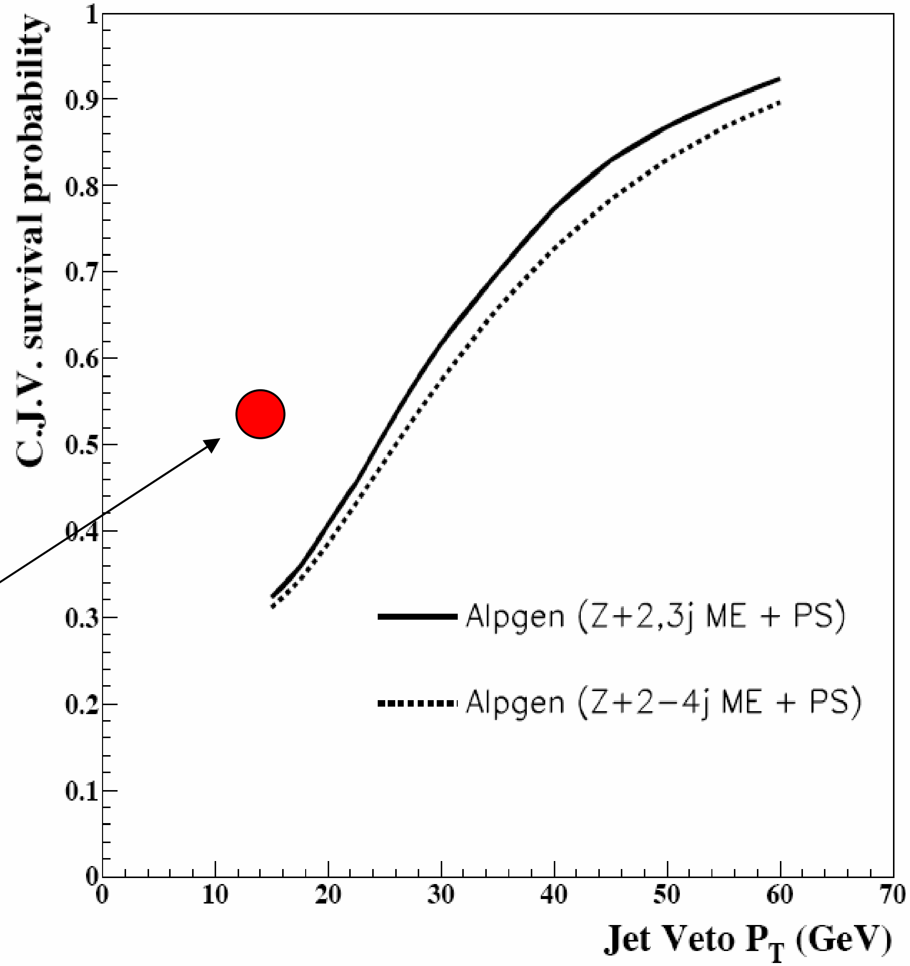


Tag jets > 20 GeV/c; 3rd jet > 8 GeV/c



ATLAS study

- ALPGEN (with mlm procedure) predicts 30-40% survival probability for Z + 2,3 jet events



MCFM prediction for 'survival probability' for W+>=2 jets (15 GeV/c for all jets) using<p_T^{jet}> as scale

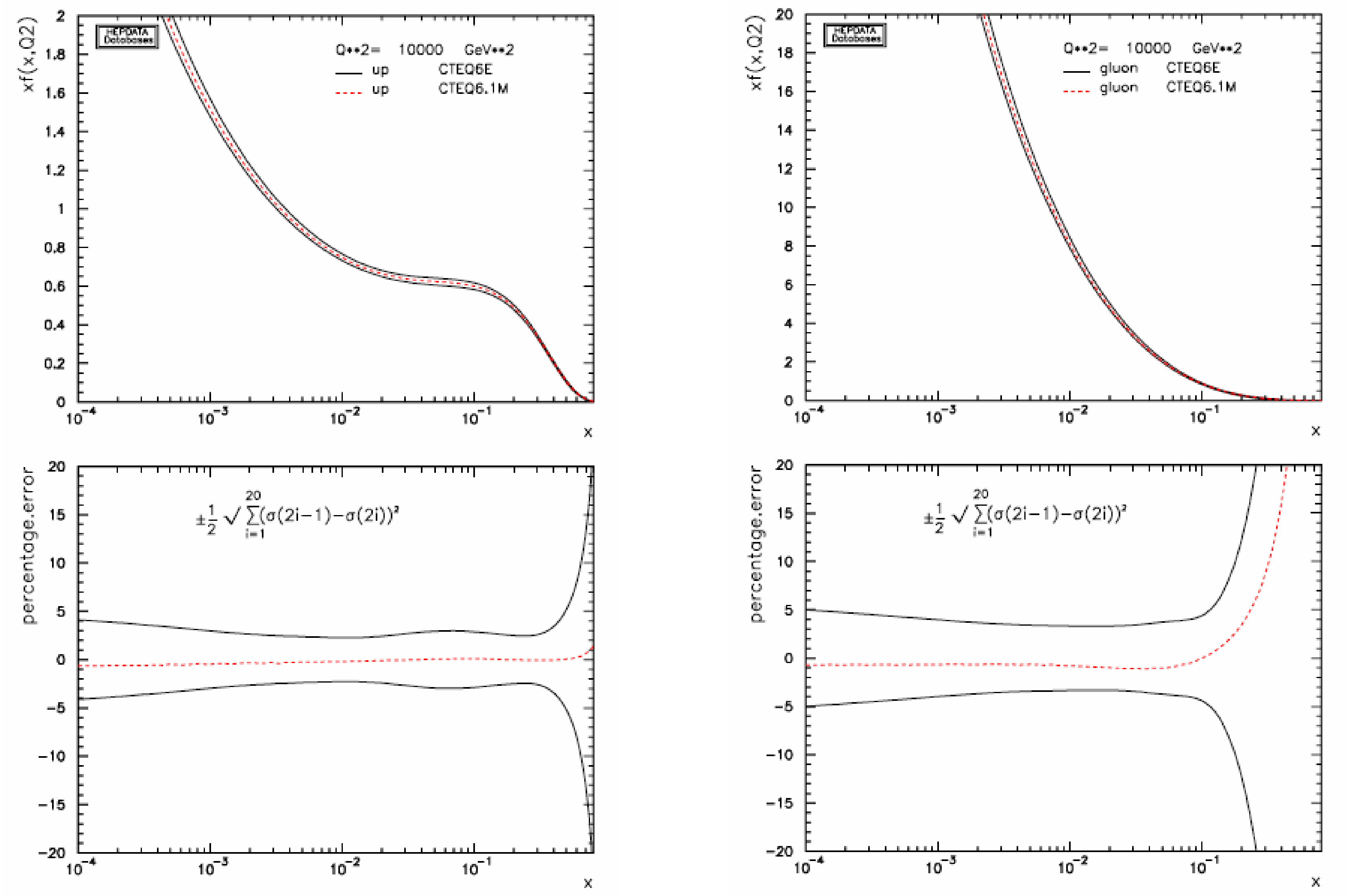
Future Plans

- Bless data predictions for W+jets
  - provide cross sections in form for easy comparison to theory by outside world
- Detailed comparisons to CKKW/ALPGEN/SHERPA/MCFM predictions
- Generate CCKW samples for LHC
  - Steve Mrenna is currently doing
- Extend study to LHC
  - ATLAS note in collaboration with Bruce Mellado

Other news:pdf's

- New α_s series/CTEQ7: see Dan Stump's talk
- New LHAPDF: see Craig Group's talk
- New tunes using CTEQ6.1: see Rick Field's talk
- "Just say no" to LO pdf's: the rest of my talk

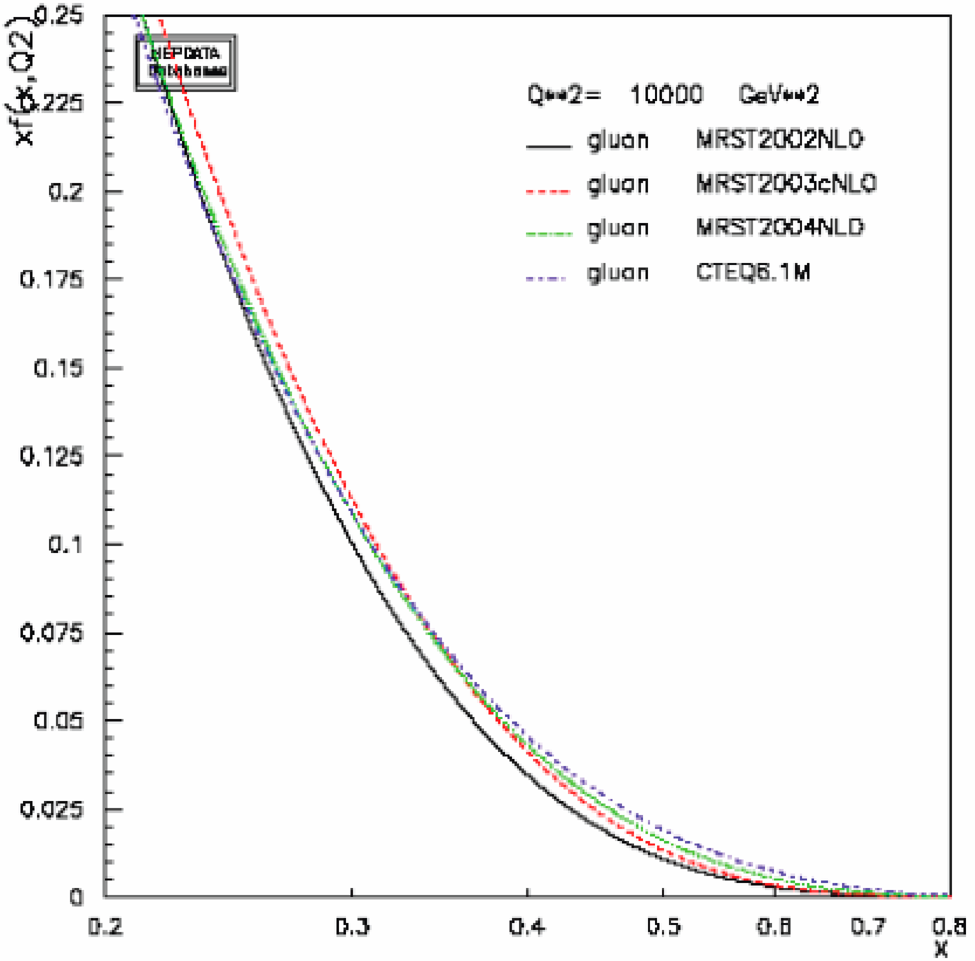
Aside:CTEQ6.1 vs CTEQ6



…relatively small changes except for high x gluon

MRST2004

- New MRST2004 pdf's now have a gluon similar to CTEQ6.1 at high x
- And thus similar predictions for jet cross sections at both the Tevatron and LHC



Run 2 jet cross section

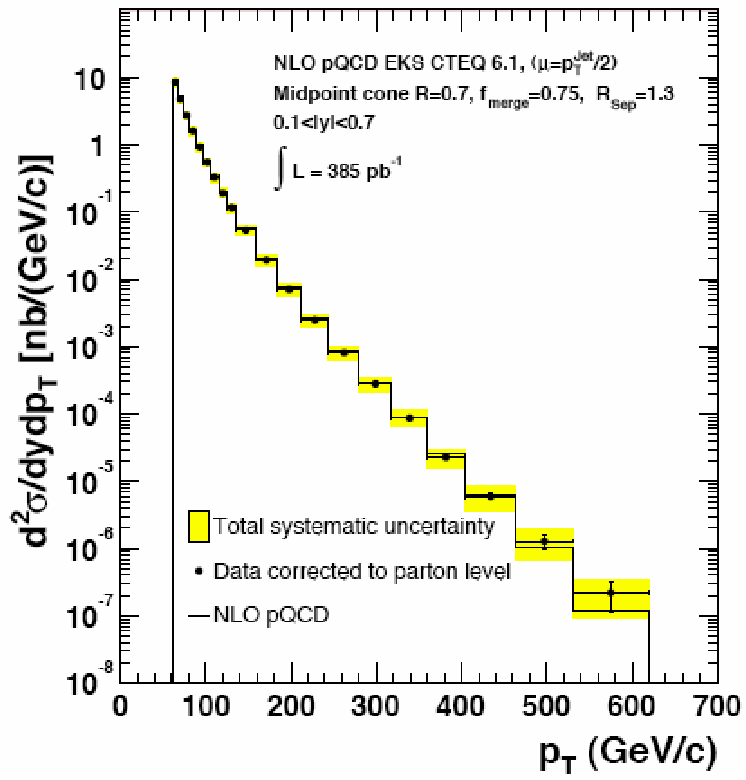


FIG. 1: *The measured inclusive jet differential cross section corrected to the parton level compared to the NLO pQCD prediction of the EKS calculation using CTEQ6.1M.*

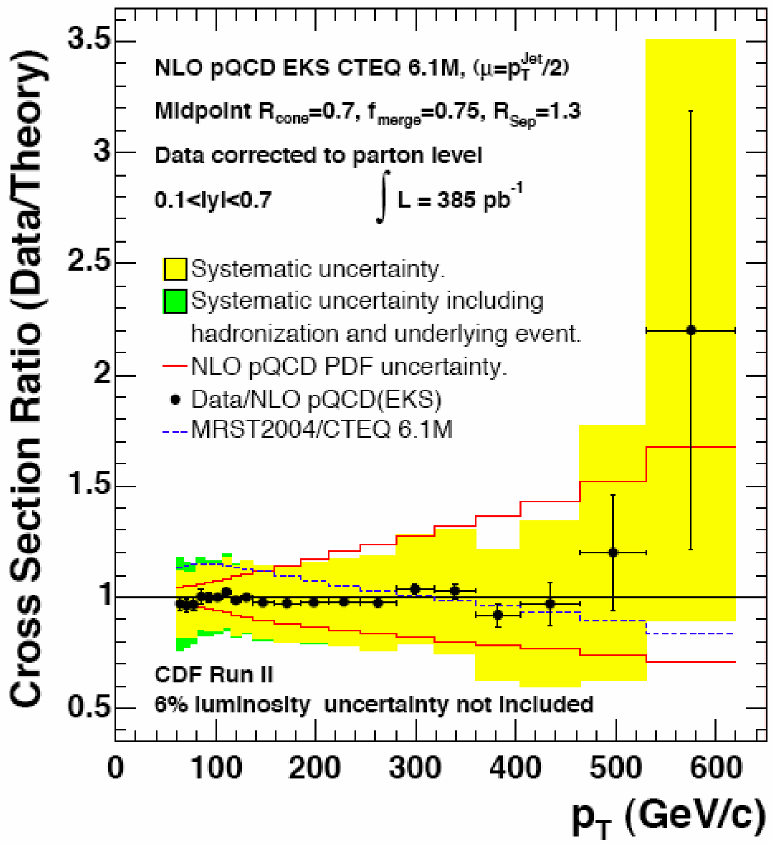


FIG. 2: *The ratio of the data corrected to the parton level over the NLO pQCD prediction of the EKS calculation using CTEQ6.1M. Also shown are the experimental systematic errors and the theoretical errors from the PDF uncertainty. The ratio of MRST2004/CTEQ6.1M is shown as the dashed line. An additional 6% uncertainty on the determination of the luminosity is not shown.*

LO vs NLO pdf's for parton shower MC's

- For NLO calculations, use NLO pdf's (duh)
- What about for parton shower Monte Carlos?
  - somewhat arbitrary assumptions (for example fixing Drell-Yan normalization) have to be made in LO pdf fits
  - DIS data in global fits affect LO pdf's in ways that may not directly transfer to LO hadron collider predictions
  - LO pdf's for the most part are outside the NLO pdf error band
  - LO matrix elements for many of the processes that we want to calculate are not so different from NLO matrix elements
  - by adding parton showers, we are partway towards NLO anyway
  - any error is formally of NLO
- (my recommendation) use NLO pdf's
  - pdf's must be + definite in regions of application (CTEQ is so by def'n)
- Note that this has implications for MC tuning, i.e. Tune A uses CTEQ5L
  - need tunes for NLO pdf's

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

...but at the end of the day this is still LO physics;
There's no substitute for honest-to-god NLO.

upbar/downbar

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TIFF (Uncompressed) decompressor
are needed to see this picture.

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gluon

similar for MRST

compare to CTEQ5L, used for most MC's

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bottom/charm

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Less difference between NLO and NNLO pdf's

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Impact on UE tunes

- 5L significantly steeper at low x and Q^2
- Need new tune to compensate

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Les Houches: Benchmark studies for LHC

- Goal: produce predictions/event samples corresponding to 1 and 10 fb^{-1}
- Cross sections will serve as
  - benchmarks/guidebook for SM expectations in the early running
    - are systems performing nominally? are our calorimeters calibrated?
    - are we seeing signs of “unexpected” SM physics in our data?
    - how many of the signs of new physics that we undoubtedly will see do we really believe?
  - feedback for impact of ATLAS data on reducing uncertainty on relevant pdf’s and theoretical predictions
  - venue for understanding some of the subtleties of physics issues
- *Companion* review article on hard scattering physics at the LHC by John Campbell, James Stirling and myself

SM benchmarks for the LHC

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are needed to see this picture.

See www.pa.msu.edu/~huston/
Les_Houches_2005/Les_Houches_SM.html
(includes CMS as well as ATLAS)

- expected cross sections for useful processes
  - inclusive jet production
    - simulated jet events at the LHC
    - jet production at the Tevatron
      - a link to a CDF thesis on inclusive jet production in Run 2
      - CDF results from Run II using the kT algorithm
  - photon/diphoton
  - Drell-Yan cross sections
  - W/Z/Drell Yan rapidity distributions
  - W/Z as luminosity benchmarks
  - W/Z+jets, especially the *Zeppenfeld* plots
  - top pairs
    - ongoing work, list of topics (pdf file)

More of benchmark webpages

- what are the uncertainties? what are the limitations of the theoretical predictions?
  - indicate scale dependence of cross sections as well as pdf uncertainties
  - how do NLO predictions differ from LO ones?
- to what extent are the predictions validated by current data?
- what measurements could be made at the Tevatron and HERA before then to add further information?

More…

- technical benchmarks
  - jet algorithm comparisons
    - midpoint vs simple iterative cone vs kT
      - top studies at the LHC
      - an interesting data event at the Tevatron that examines different algorithms
    - Building Better Cone Jet Algorithms
      - one of the key aspects for a jet algorithm is how well it can match to perturbative calculations; here is a 2-D plot for example that shows some results for the midpoint algorithm and the CDF Run 1 algorithm (JetClu)
      - here is a link to Fortran/C++ versions of the CDF jet code
  - fits to underlying event for 200 540, 630, 1800, 1960 GeV data
    - interplay with ISR in Pythia 6.3
    - establish lower/upper variations
    - extrapolate to LHC
    - effect on target analyses (central jet veto, lepton/photon isolation, top mass?)

…plus more benchmarks that I have no time to discuss

- variation of ISR/FSR a la CDF (study performed by Un-Ki Yang)
  - low ISR/high ISR
  - FSR
  - power showers versus wimpy showers a la Peter Skands
  - number of additional jets expected due to ISR effects (see also Sudakov form factors)
  - impact on top analyses
  - effect on benchmarks such as Drell-Yan and diphoton production
    - goal is to produce a range for ISR predictions that can then be compared at the LHC to Drell-Yan and to diphoton data
- Sudakov form factor compilation
  - probability for emission of 10, 20, 30 GeV gluon in initial state for hard scales of 100, 200, 500, 1000, 5000 GeV for quark and gluon initial legs
  - see for example, similar plots for quarks and gluons for the Tevatron from Stefan Gieseke
- predictions for W/Z/Higgs p_T and rapidity at the LHC
  - compare ResBos(-A), joint-resummation and Berger-Qiu for W and Z

Summary

- Broad range of tools being developed for the Tevatron and LHC including those dealing with pdf's
  - up to us to make use of them/drive the development of what we need
- Program for SM benchmarks for LHC underway
  - www.pa.msu.edu/~huston/Les_Houches_2005/Les_Houches_SM.html