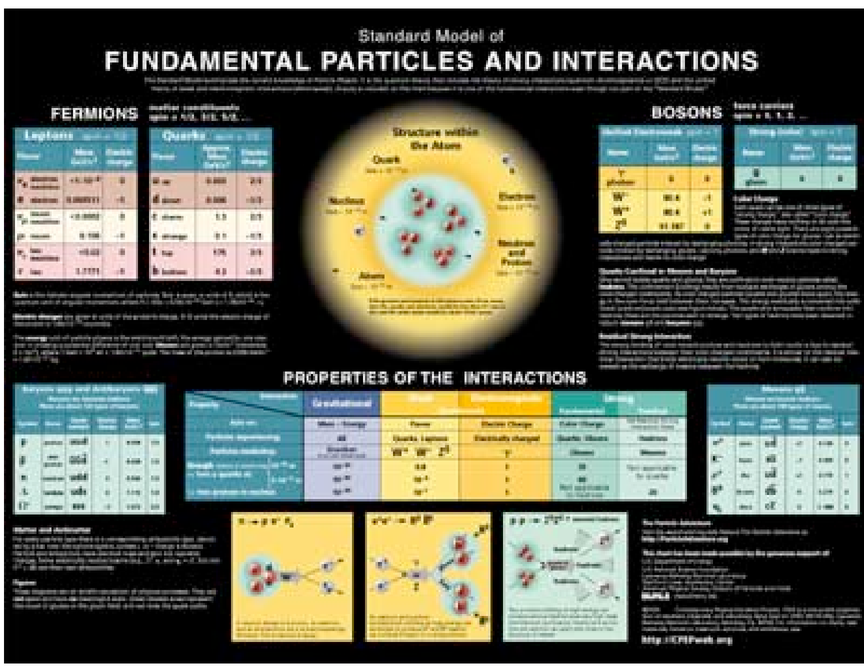
Discovering the Standard Model during the first year(s) of the LHC (and reliability of SM predictions)

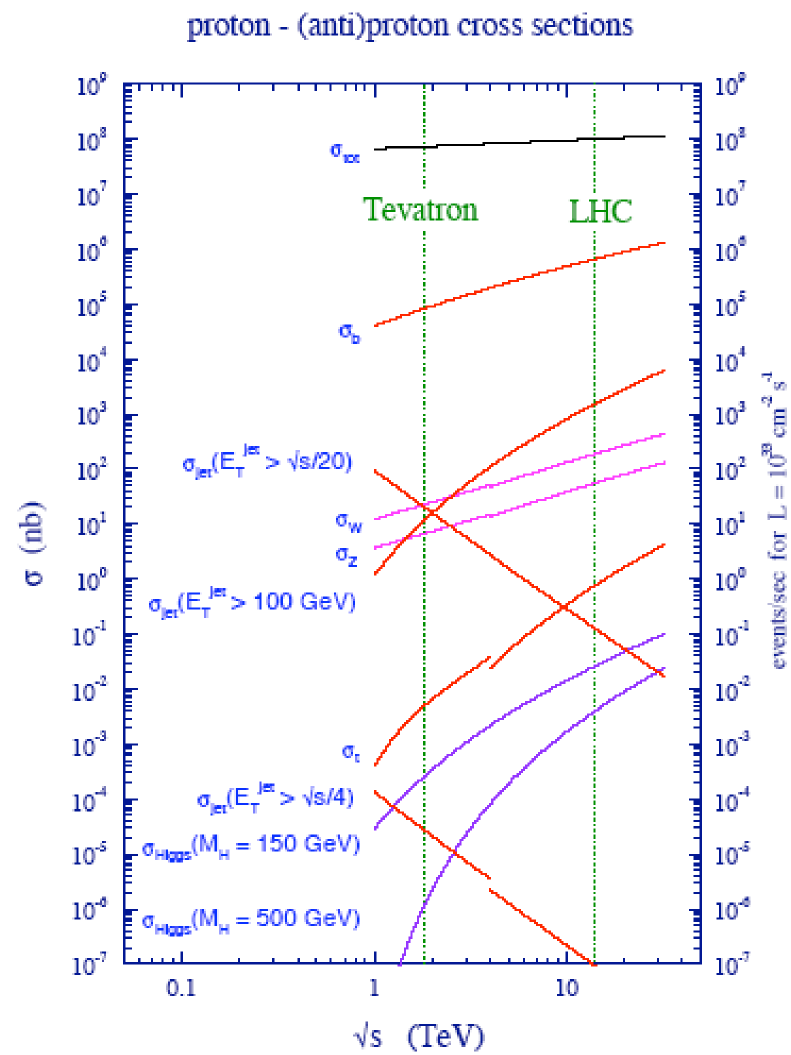
J. Huston

Michigan State University



Introduction

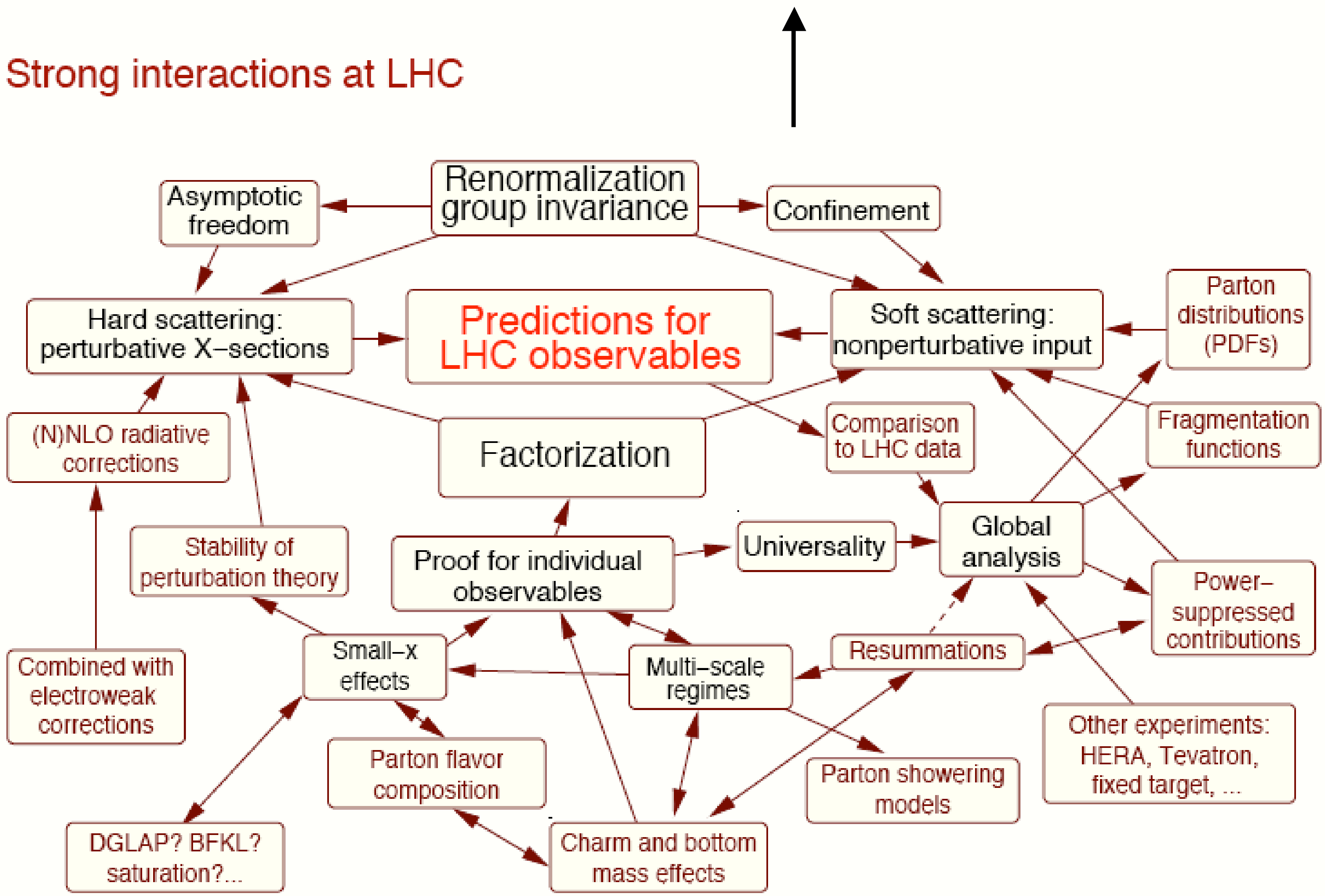
- Before we publish BSM discoveries from the early running of the LHC, we want to make sure that we measure/understand SM cross sections
  - detector and reconstruction algorithms operating properly
  - SM physics properly understood
  - SM backgrounds to BSM physics correctly taken into account
- Will have program to measure production of SM processes: jets, W/Z (+jets), heavy flavor during first year



SM Predictions

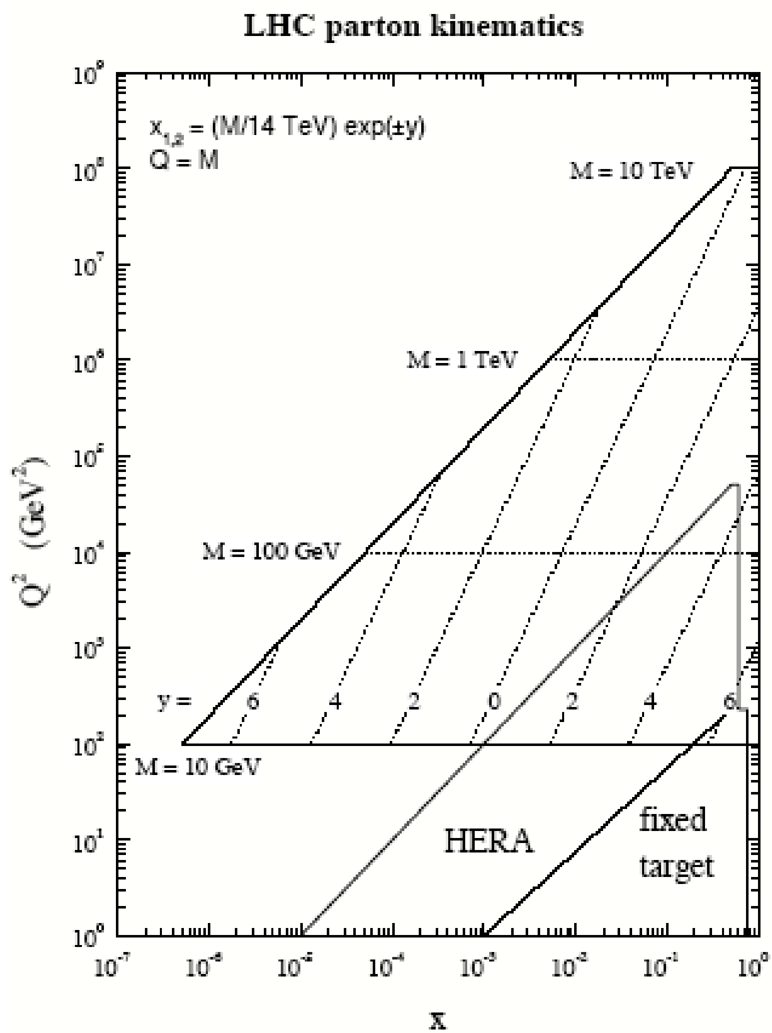
Pavel Nadolsky, EFI Mini-Symposium, U. of Chicago, March 14, 2005

Strong interactions at LHC



Scattering at the LHC

- Experience at the Tevatron is very useful, but scattering at the LHC is not necessarily just “rescaled” scattering at the Tevatron
- Small typical momentum fractions *x* in many key searches
  - dominance of gluon and sea quark scattering
  - large phase space for gluon emission
  - intensive QCD backgrounds



Uncertainties on SM cross sections

- Perturbative calculations have a realistic normalization only at NLO
- Parton-level calculations have been performed for all 2->2 and some 2->3 processes
  - state of the art is W/Z+2 jets
  - W/Z+3 jets perhaps in 2 years
    - problems with multi-leg virtual integrations
    - many loop integrals
    - enormous expressions, large numerical cancellations

- See www.cedar.ac.uk/hepcode/ for collection of NLO codes, such as

AYLEN/EMILIA (de Florian et.al.): $pp \to (W,Z) + (W,Z,\gamma)$

DIPHOX (Aurenche et.al.): $pp \to \gamma j, \gamma\gamma, \gamma^* p \to \gamma j$

HQQB (Dawson et.al.): $pp \to t\bar{t}H, b\bar{b}H$

MCFM (Campbell, Ellis): $pp \to (W,Z) + (0,1,2)\,j,\ (W,Z) + b\bar{b}$

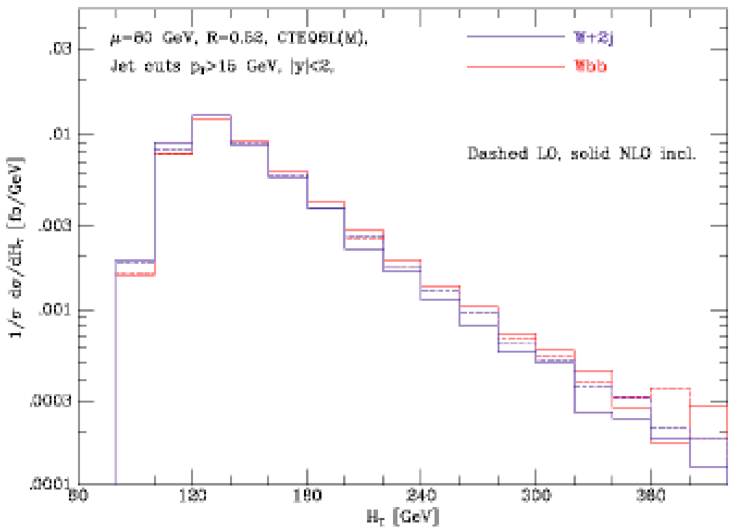
NLOJET++ (Nagy): $pp \to (2,3)\,j,\ ep \to (3,4)\,j,\ \gamma^* p \to (2,3)\,j$

VBFNLO (Figy et.al.): $pp \to (W,Z,H) + 2\,j$

NLO vs LO predictions

LO->NLO may not be just a K-factor

Don't rely just on LO predictions J. Campbell, J. Huston; hep-ph/0405276



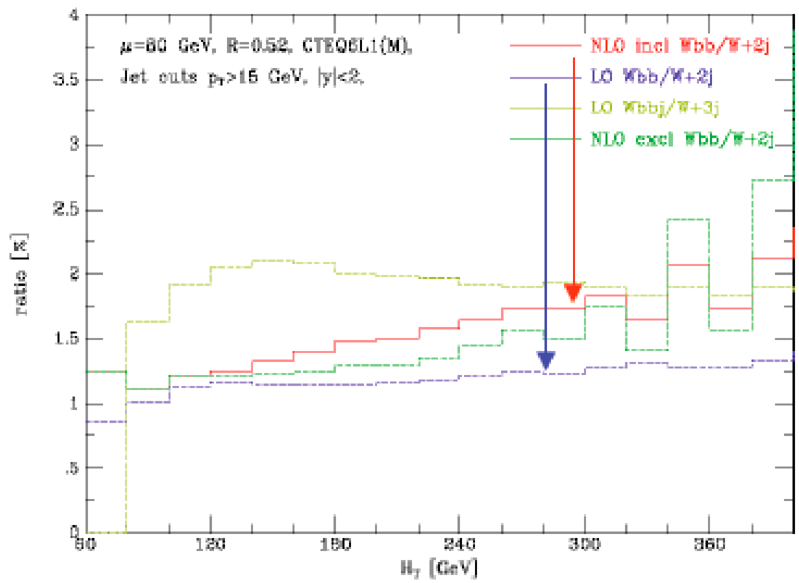


Figure 12: The H_T distributions for $Wb\bar{b}(j)$ and $Wjj(j)$, normalized to the same area.

Wbb and Wjj have similar H_T distribution at LO; different at NLO
Consequence: H_T not used in fitting for heavy flavor fraction in top searches in W + jets channel at CDF

The much-maligned wish-list

- Missing many needed NLO computations — Campbell

An experimenter's wishlist

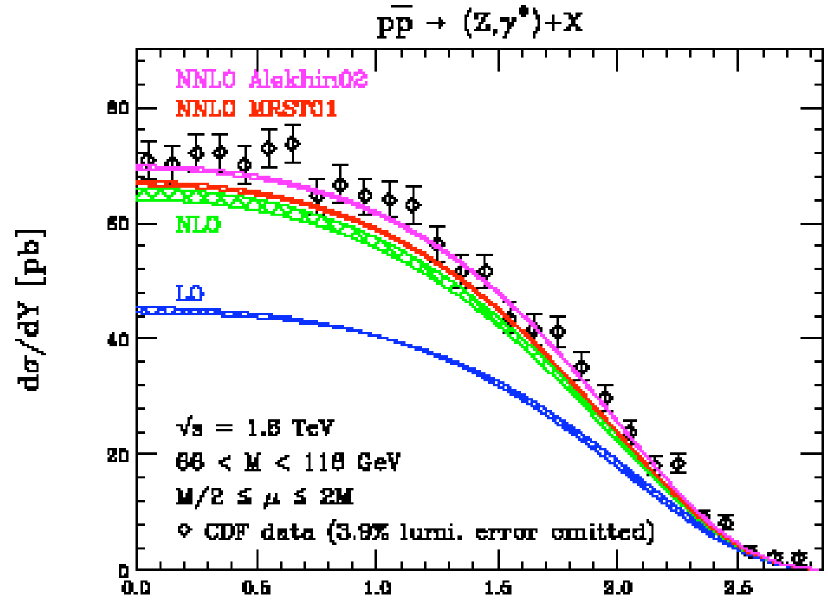
- Hadron collider cross-sections one would like to know at NLO

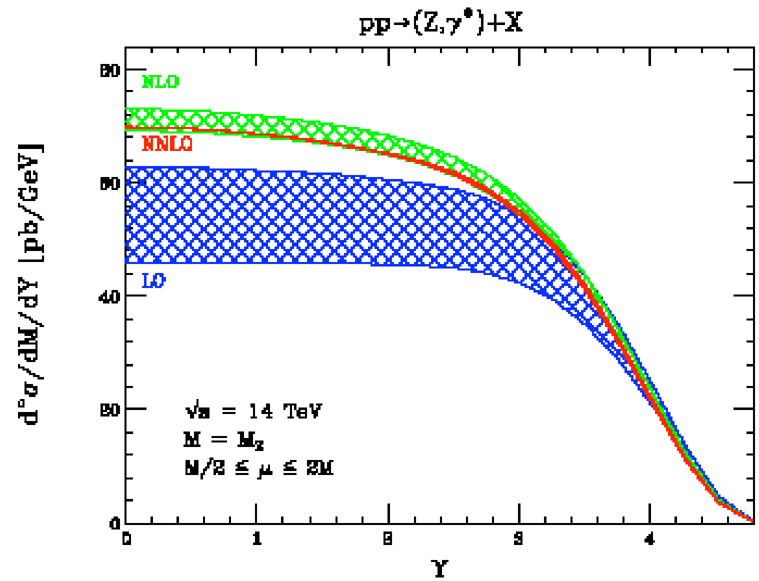
Run II Monte Carlo Workshop, April 2001

Single boson	Diboson	Triboson	Heavy flavour
$W+\leq 5j$	$WW+\leq 5j$	$WWW+\leq 3j$	$t\bar{t}+\leq 3j$
$W+b\bar{b}+\leq 3j$	$WW+b\bar{b}+\leq 3j$	$WWW+b\bar{b}+\leq 3j$	$t\bar{t}+\gamma+\leq 2j$
$W+c\bar{c}+\leq 3j$	$WW+c\bar{c}+\leq 3j$	$WWW+\gamma\gamma+\leq 3j$	$t\bar{t}+W+\leq 2j$
$Z+\leq 5j$	$ZZ+\leq 5j$	$Z\gamma\gamma+\leq 3j$	$t\bar{t}+Z+\leq 2j$
$Z+b\bar{b}+\leq 3j$	$ZZ+b\bar{b}+\leq 3j$	$WZZ+\leq 3j$	$t\bar{t}+H+\leq 2j$
$Z+c\bar{c}+\leq 3j$	$ZZ+c\bar{c}+\leq 3j$	$ZZZ+\leq 3j$	$t\bar{b}+\leq 2j$
$\gamma+\leq 5j$	$\gamma\gamma+\leq 5j$		$b\bar{b}+\leq 3j$
$\gamma+b\bar{b}+\leq 3j$	$\gamma\gamma+b\bar{b}+\leq 3j$		
$\gamma+c\bar{c}+\leq 3j$	$\gamma\gamma+c\bar{c}+\leq 3j$		
	$WZ+\leq 5j$		
	$WZ+b\bar{b}+\leq 3j$		
	$WZ+c\bar{c}+\leq 3j$		
	$W\gamma+\leq 3j$		
	$Z\gamma+\leq 3j$		

NNLO

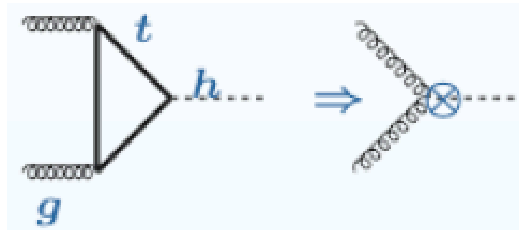
- A few cross sections have been calculated to NNLO
  - inclusive W/Z
  - W/Z/Higgs rapidity
  - inclusive jet perhaps still 2 years off
- Often effect is just a K-factor
  - but needed for precision physics such as with W/Z



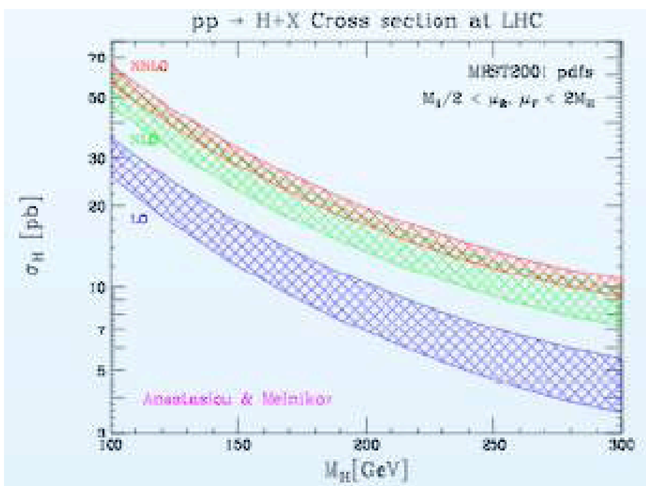


NNLO essential for Higgs

- The dominant production mode is gluon fusion through a top quark loop:



- Large scale dependence at NLO; $K \approx 100\%$!
- NNLO corrections studied by several groups (Harlander, Kilgore; Anastasiou, Melnikov; Ravindran et.al.)



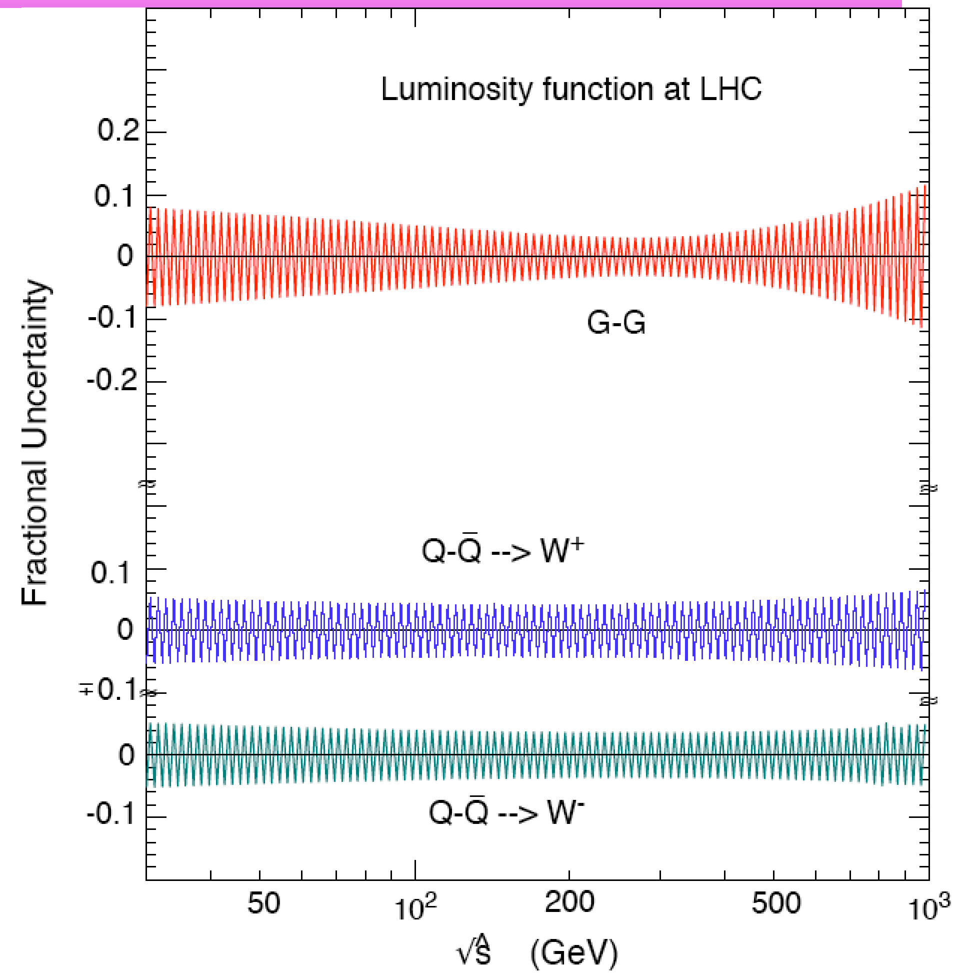
- 20% scale dependence at NNLO
- NNLO corrections are $\approx 30\%$

$\Rightarrow$ series appears convergent

Frank Petriello; talk at Enrico Fermi Institute Symposium

PDF uncertainties

- pdf uncertainties only make sense at NLO (or higher) since this is the first order at which the normalization is believable
- In most kinematic regions of interest at the LHC, pdf uncertainties are small
  - one exception is high E_T jet production
- I've heard people say that the LHC will spend its first year measuring pdf's
- Measuring pdf's is precision physics
- The LHC will spend its first year being *constrained* by pdf's

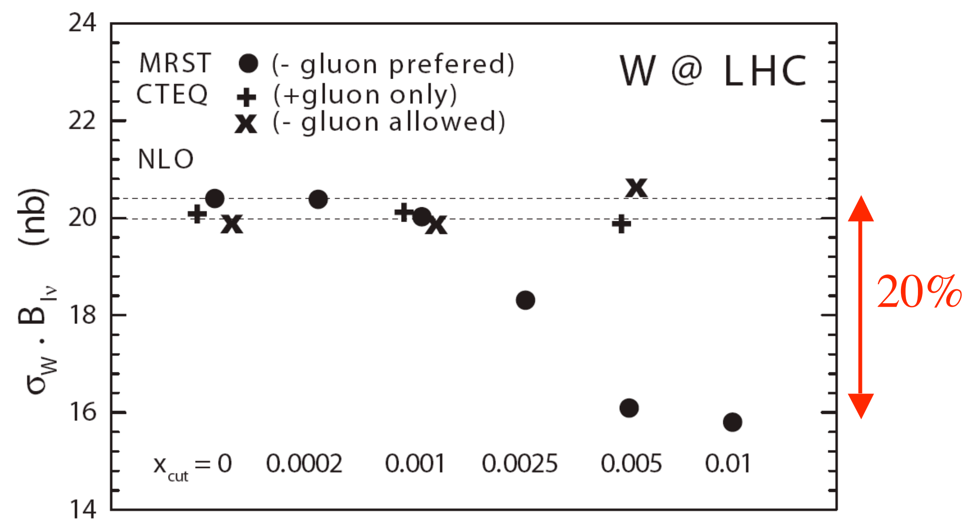


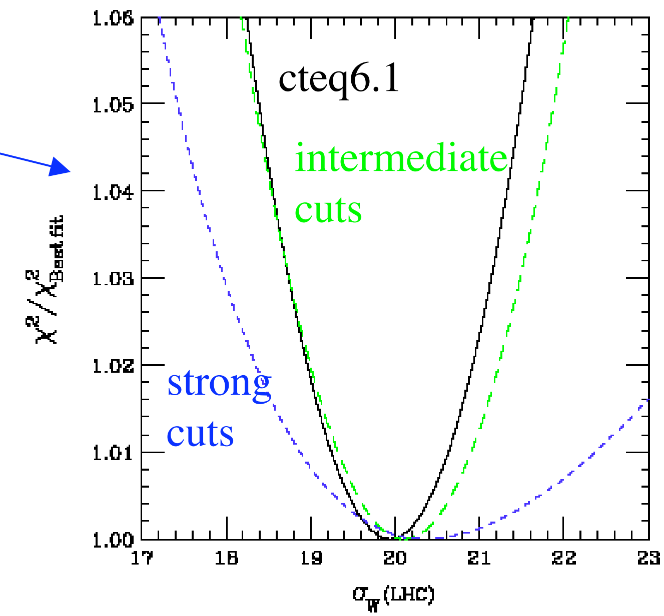
- NLO predictions for LHC under good control if NLO formalism is adequate for LHC

Les Houches 2005

Validity of NLO DGLAP

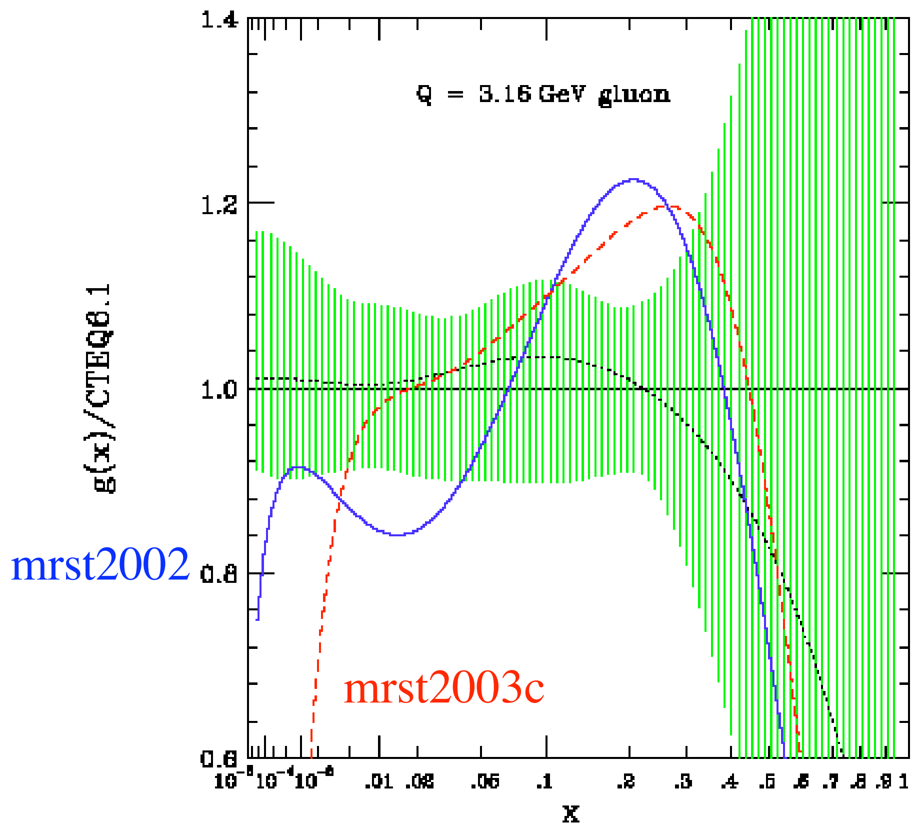
- Is there a *tension* between HERA and Tevatron data requiring NNLO DGLAP to resolve?
  - MRST study: hep-ph/0308087
  - W cross section at LHC drops 20% when data below x=.005 are removed from fit
  - implications for use of W σ as luminosity benchmark
- Recent CTEQ study indicates as more severe cuts 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

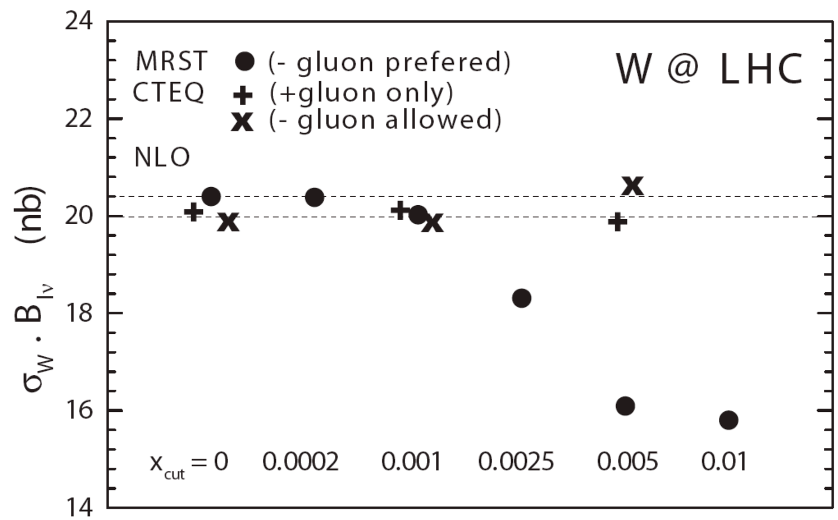


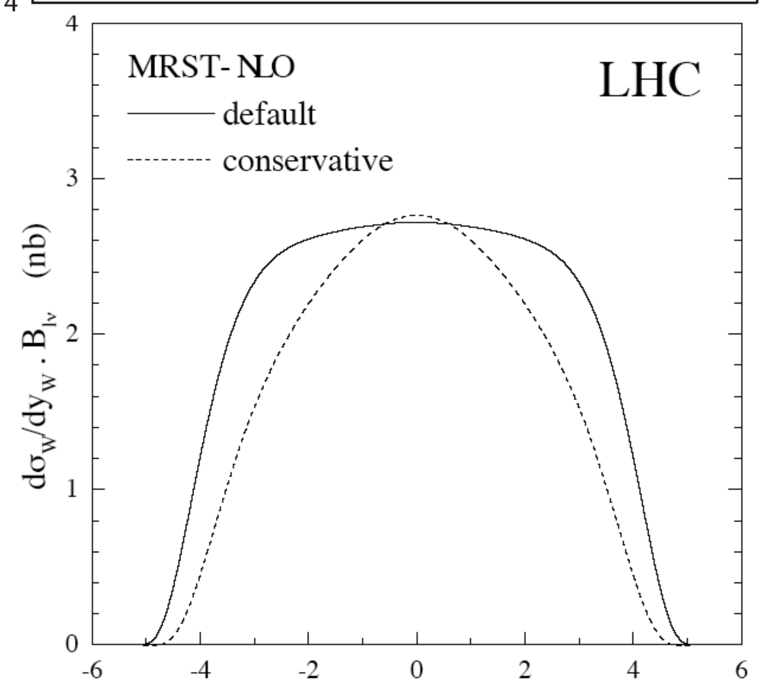


Negative gluon

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

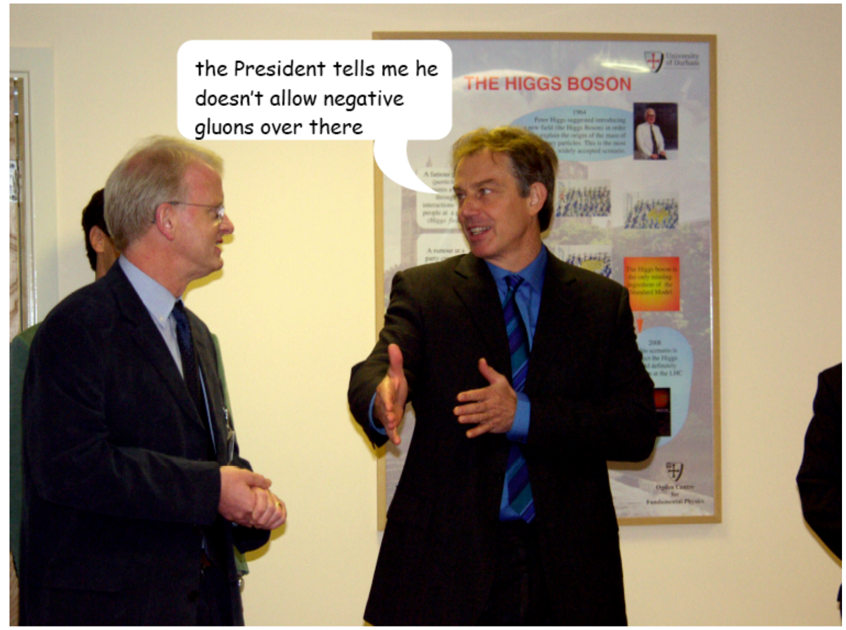


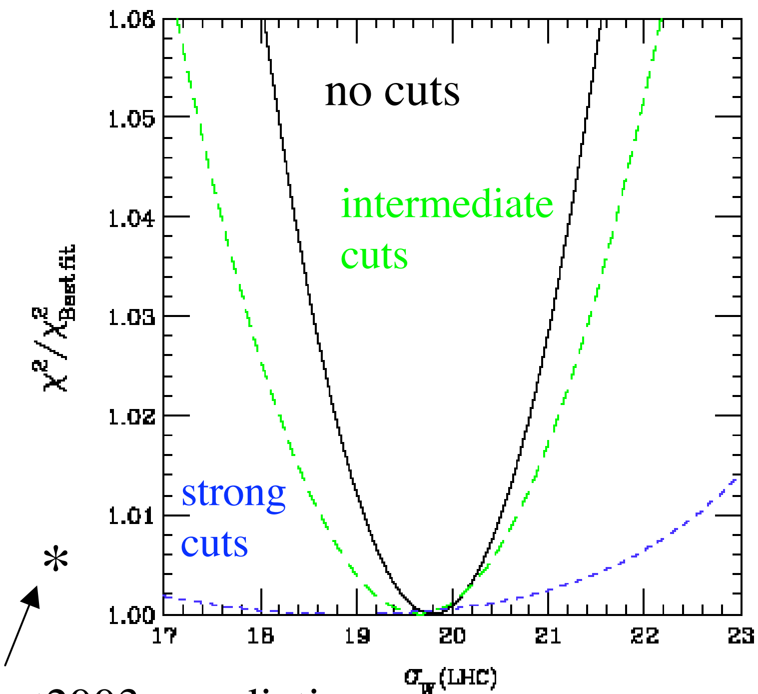




NLO stability

- 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

---

hep-ph/0502080

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

- 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*

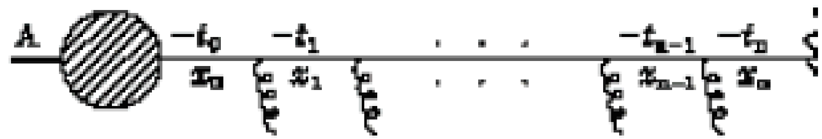
In new version, all error pdf's can be kept in memory at same time. PDF uncertainty for any cross section can be calculated by weights

PDF weight technique with parton showers

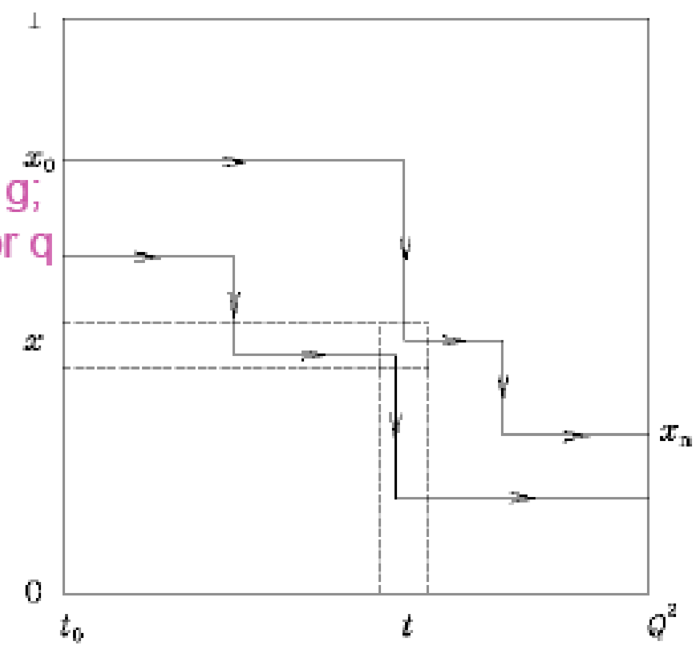
- An error may be introduced when using this technique with parton shower Monte Carlos
- The backward evolution in the initial state depends not only on the value of the pdf at a specific x and Q^2 value but also the slope of the pdf in going to higher x and lower Q^2
- In ISR, parton evolves backwards 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.

0.4/0.34 → 0.25



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

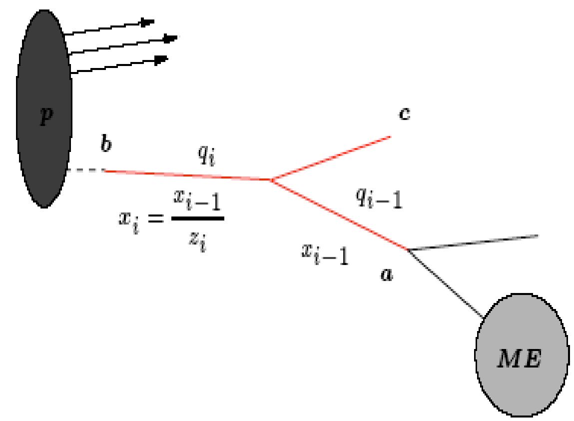
Stefan Gieseke

Institut für Theoretische Physik
Universität Karlsruhe, 76128 Karlsruhe, Germany
gieseke@particle.uni-karlsruhe.de

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.

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

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

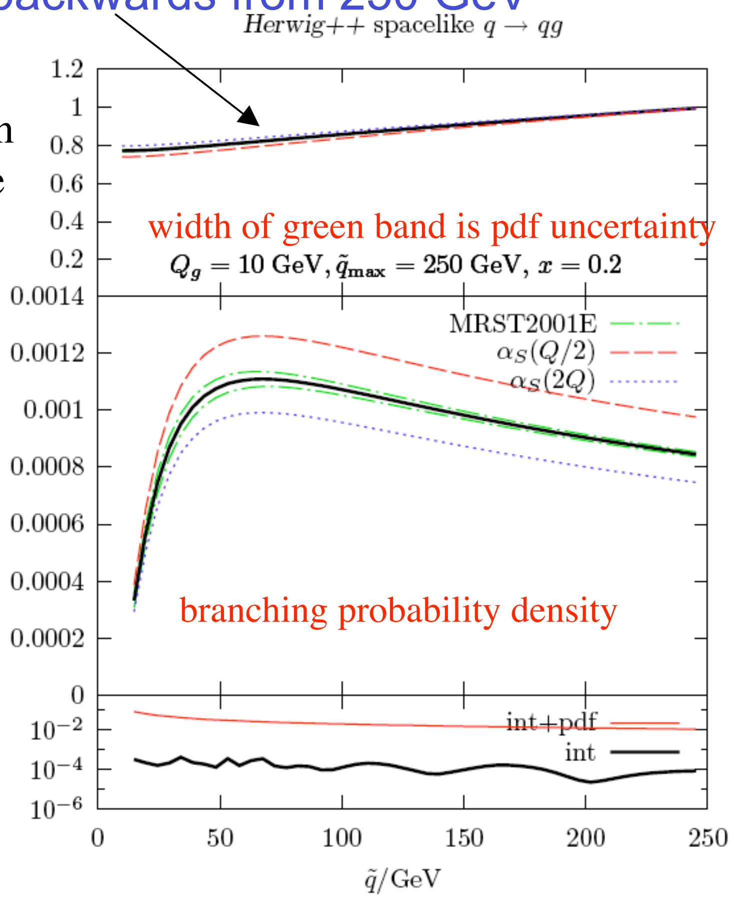
$$\boldsymbol{p}_{\perp i}^2 = (1 - z_i)^2 \tilde{q}_i^2 - z_i Q_g^2 .$$

Q_g closely related to parton shower cutoff.

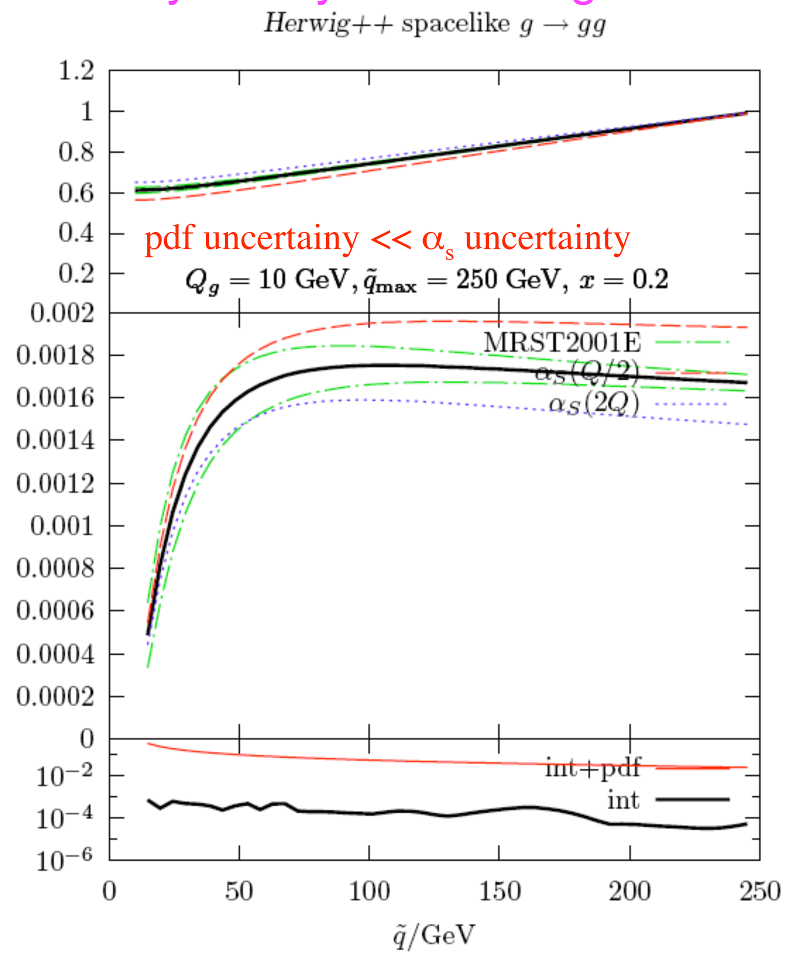
Uncertainties on Sudakov form factors

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



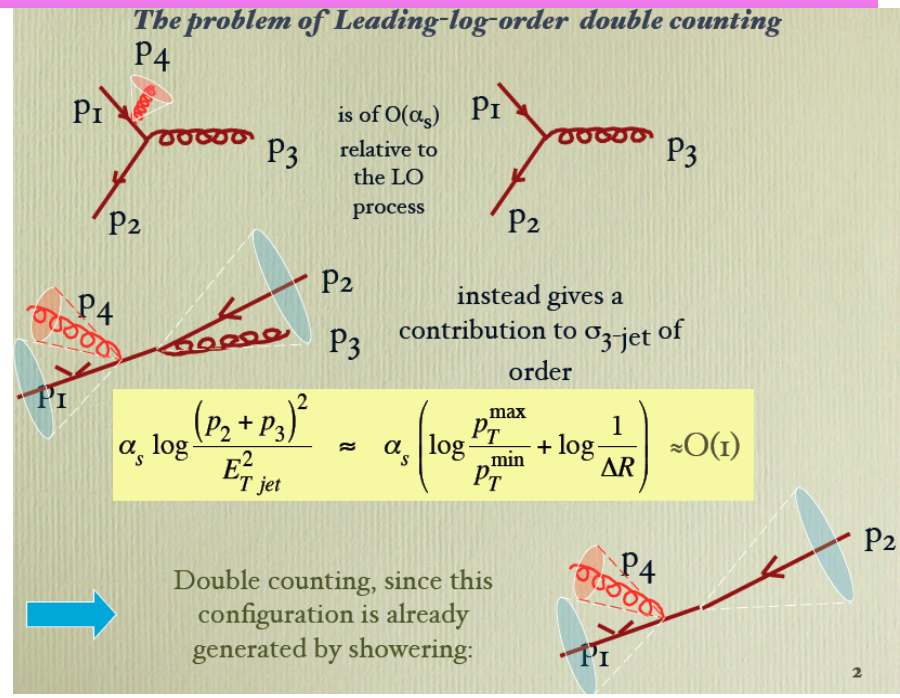
Gluons like to radiate more than quarks; probability is only 60% for a gluon of x=0.2



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

Matrix element and parton shower predictions

- For best (LO) predictions at the LHC, often want to combine matrix element and parton shower predictions
  - matrix elements can describe configurations with hard jets better
  - with parton shower programs, you include the effects of multiple gluon radiation and hadronization
- …but need to control size of unwelcome logs when interfacing ME and PS
- mlm and CKKW approaches exist for controlling logs
- Both approaches describe Tevatron W/Z + jets data well
  - hopefully comparisons soon
- Steve Mrenna and Peter Richardson have studied systematic errors for these techniques



hep-ph/0312274

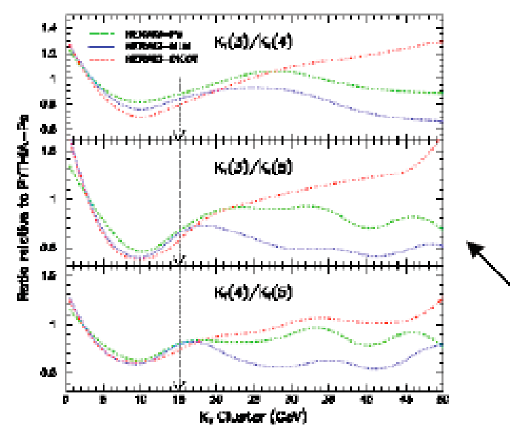
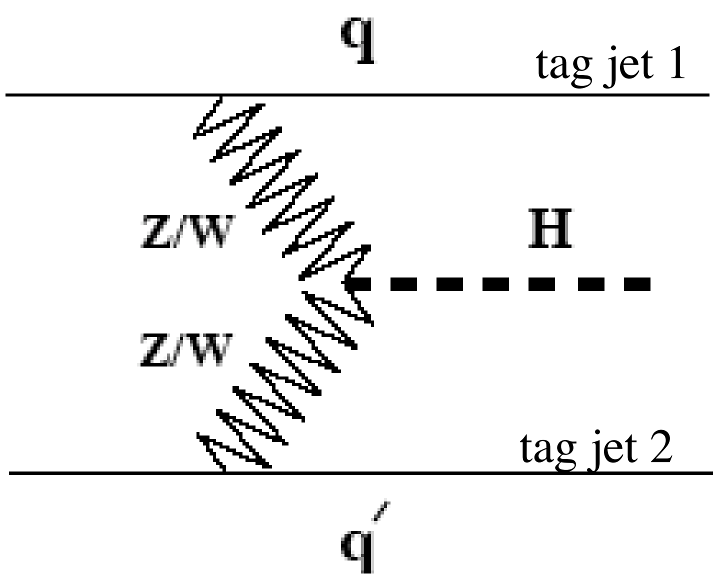


Figure 26: Similar to Fig. 19 but comparing the distributions from HERWIG and PY using the pseudo-shower procedure, HERWIG using the MLM procedure, and HERWIG using the CKKW procedure for a matching scale of 15 GeV.

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 exchange

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
- 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

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; $B(W\to e\nu, \mu\nu)$ 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?

More from Dieter's talk

Get answers from $W + \geq 2$ jet data

$p_{Tj_1}, p_{Tj_2} \gtrsim 30$ GeV $\quad |\eta_{j_1} - \eta_{j_2}| > 2 \ldots 3$

p_{Tj_3} as soft as possible

- Fraction of events r_{2+n} with $n = 1, 2, 3 \ldots$ additional jets of $p_T > p_{Tmin}$
- p_{Tmin} dependence of r_{2+n}
- rapidity distribution of extra jets $\frac{d\sigma}{d\eta_3^*}$

By how much can a central jet veto reduce the Wjj background?

i.e. please tell us your jet detection efficiencies .... or provide uncorrected r_{2+n}

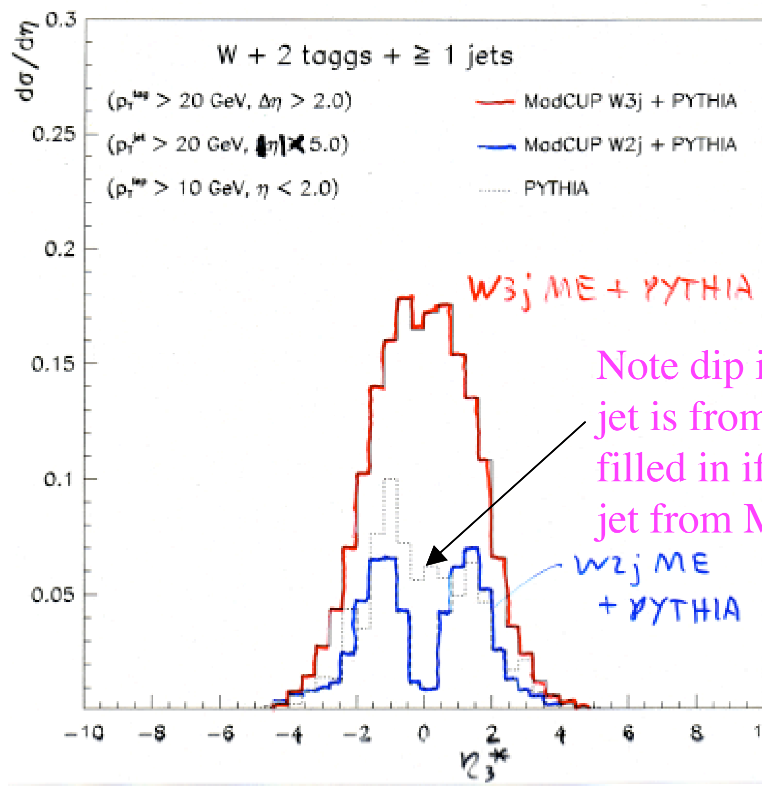
Study by E. Richter-Was

QCD Wjj events @ Tevatron, $W \to \mu\nu$

$B\sigma(\Delta\eta_{tag} > 2, \geq 2 jets) \approx 8$ pb

$B\sigma($ " $, \geq 3 jets) \approx 1.3$ pb

for $p_{Tj} > 20$ GeV



$\eta_3^* = \eta_3 - \frac{\eta_1 + \eta_2}{2}$

$p_{T1} > p_{T2} > p_{T3} \ldots$

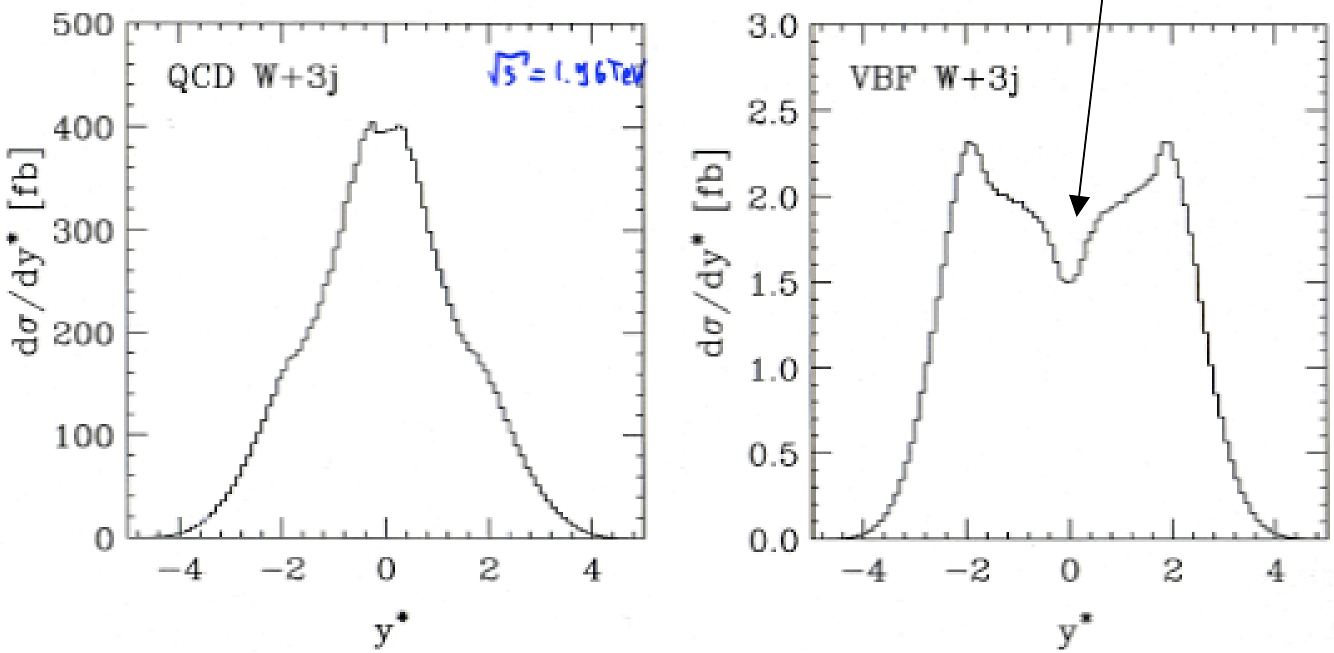
More from Dieter

Rapidity distribution of 3rd (softest) jet (LO ME

$p_T^{tag} > 30$ GeV $\quad p_{T3} > 15$ GeV

$\Delta\eta_{tag} = |\eta_1 - \eta_2| > 2$

VBF naturally has a dip at y*=0

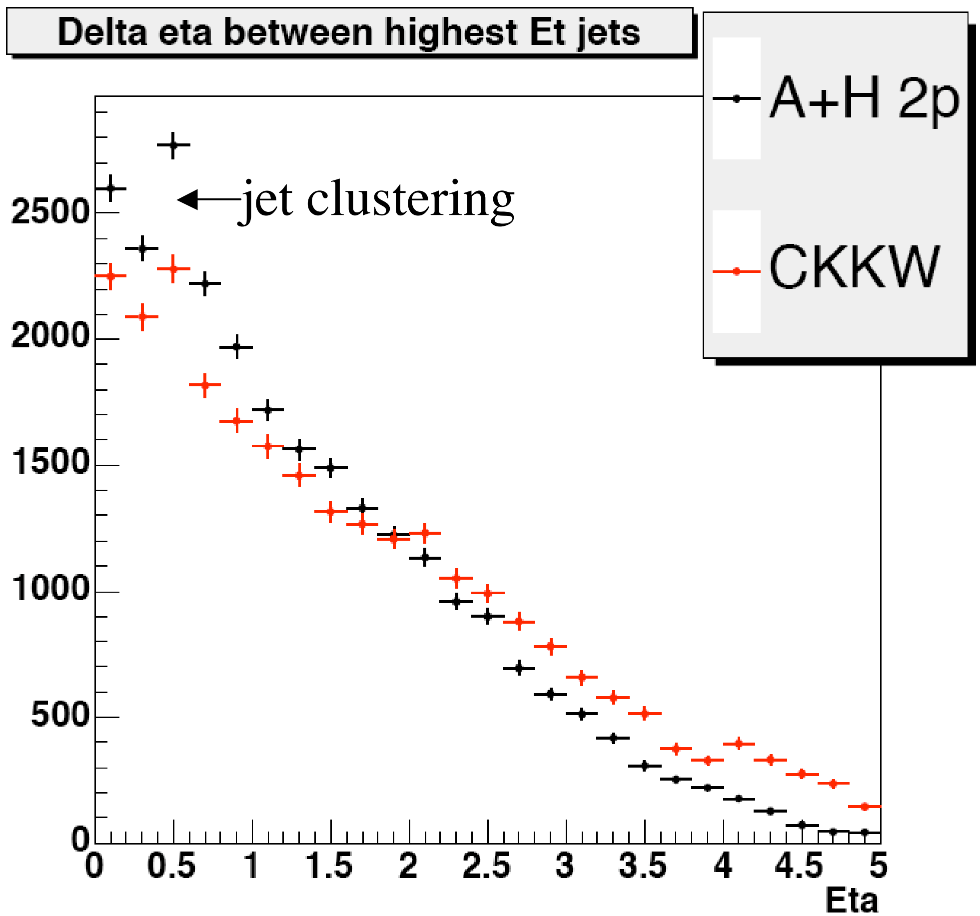


$y^* = y_3 - \frac{y_1 + y_2}{2}$

Δη of tag jet plots

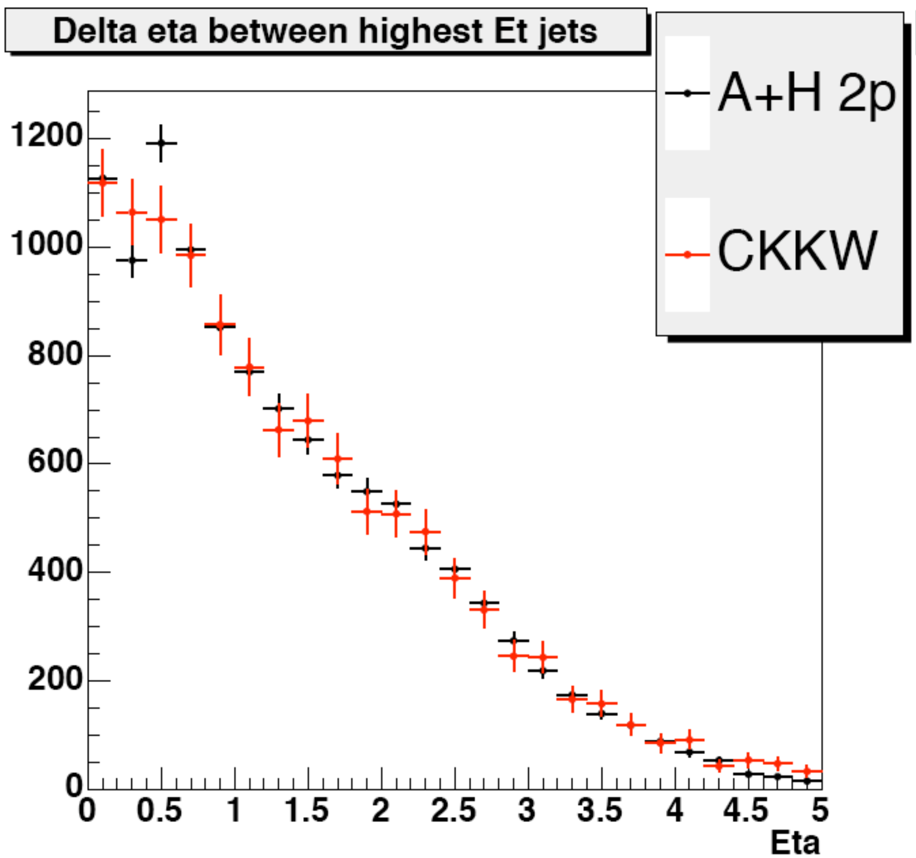
- Look at η difference between tagging jets
- Compare to Alpgen W + 2 partons) interfaced to Herwig for additional parton showering and to CKKW sample (generated with Madgraph interfaced to Pythia)
- 3 different E_T cuts on tagging jets
  - all jets defined using a cone of 0.4

E_T of tag jets > 8 GeV/c

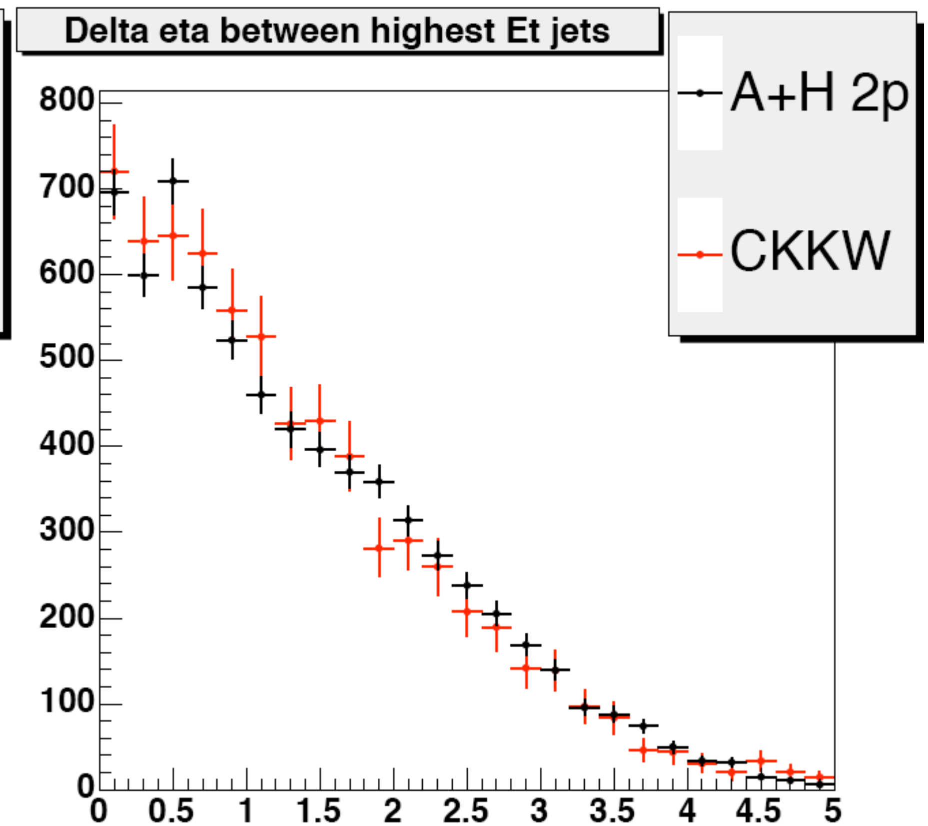


Δη of tag jet plots

E_T of tag jets > 15 GeV/c



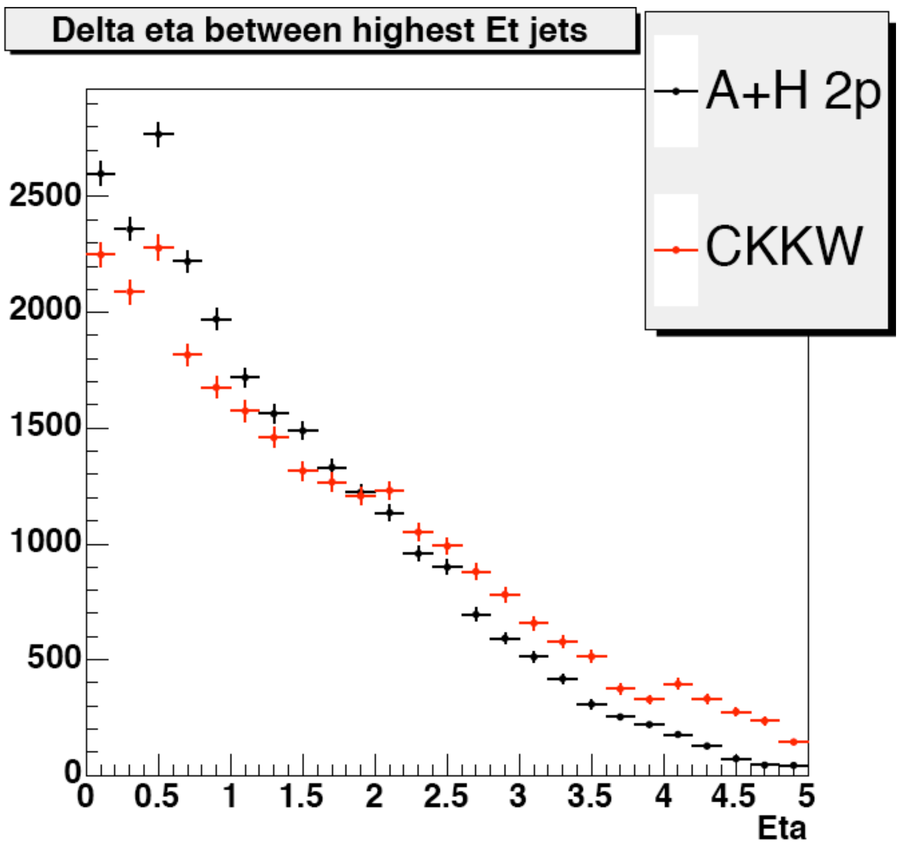
E_T of tag jets > 20 GeV/c

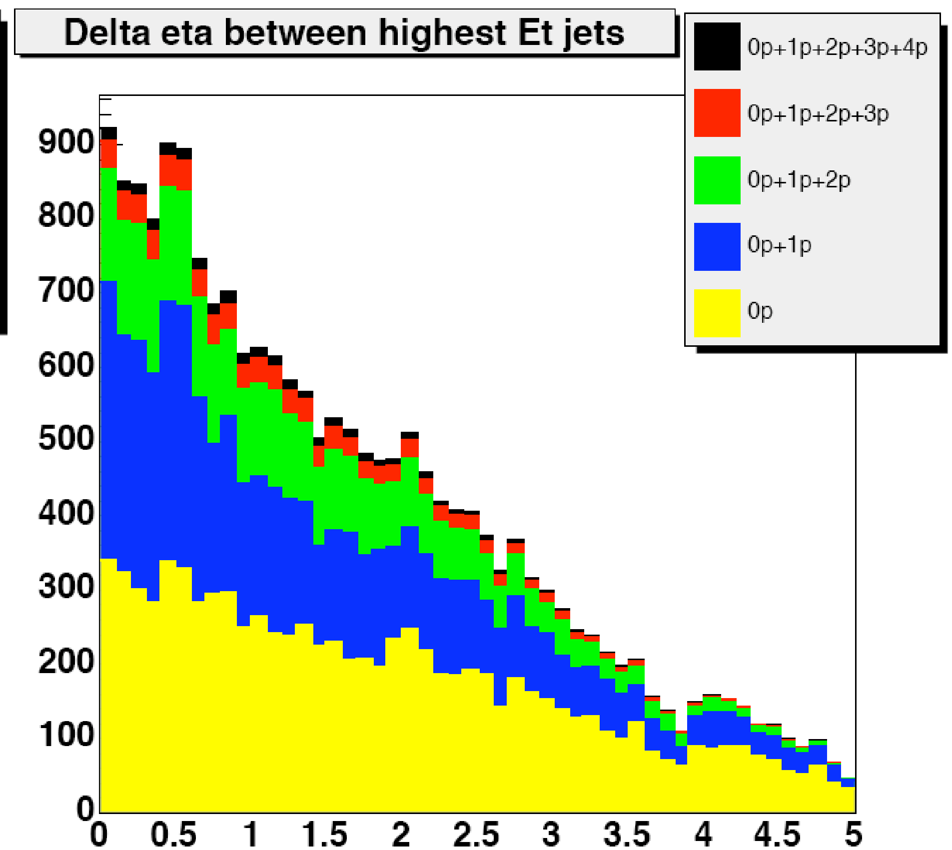


Both A+H and CKKW seem to describe the data reasonably well.

E_T of tag jets > 8 GeV/c

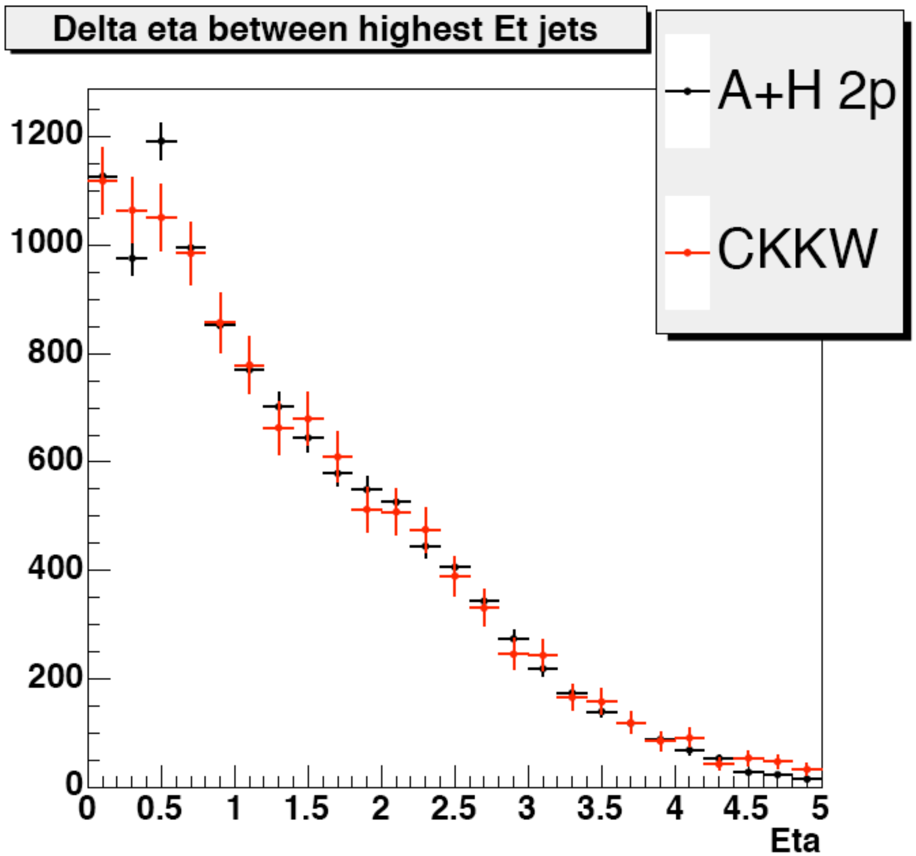
- CKKW decomposition

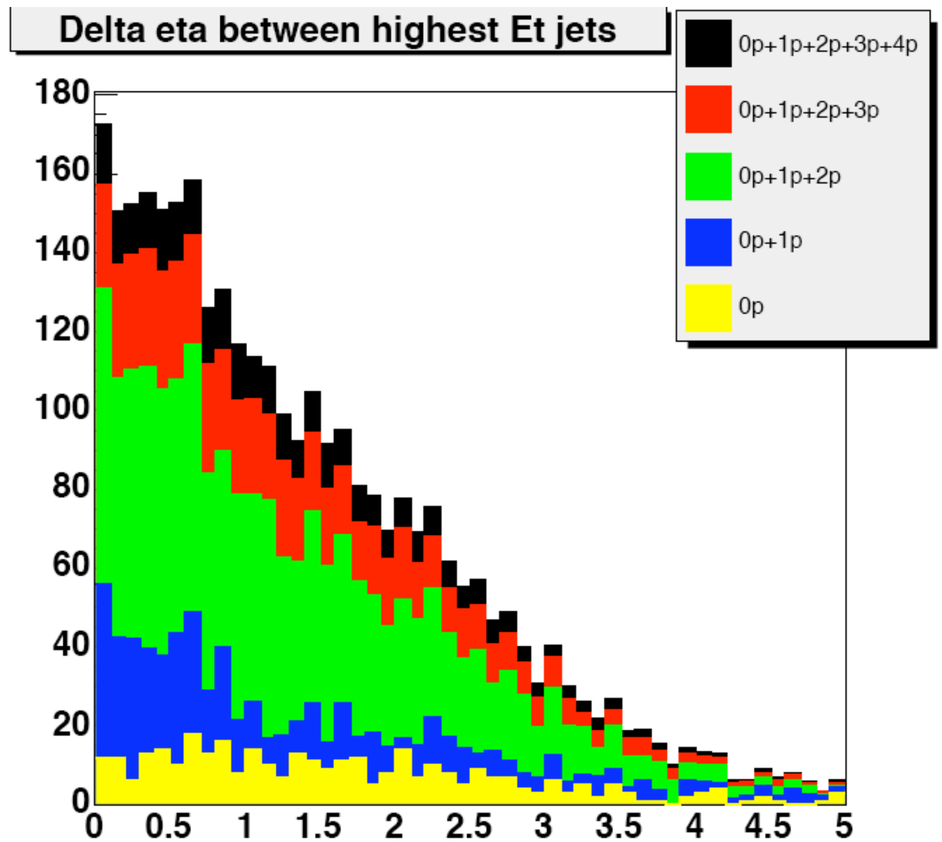




E_T of tag jets > 15 GeV/c

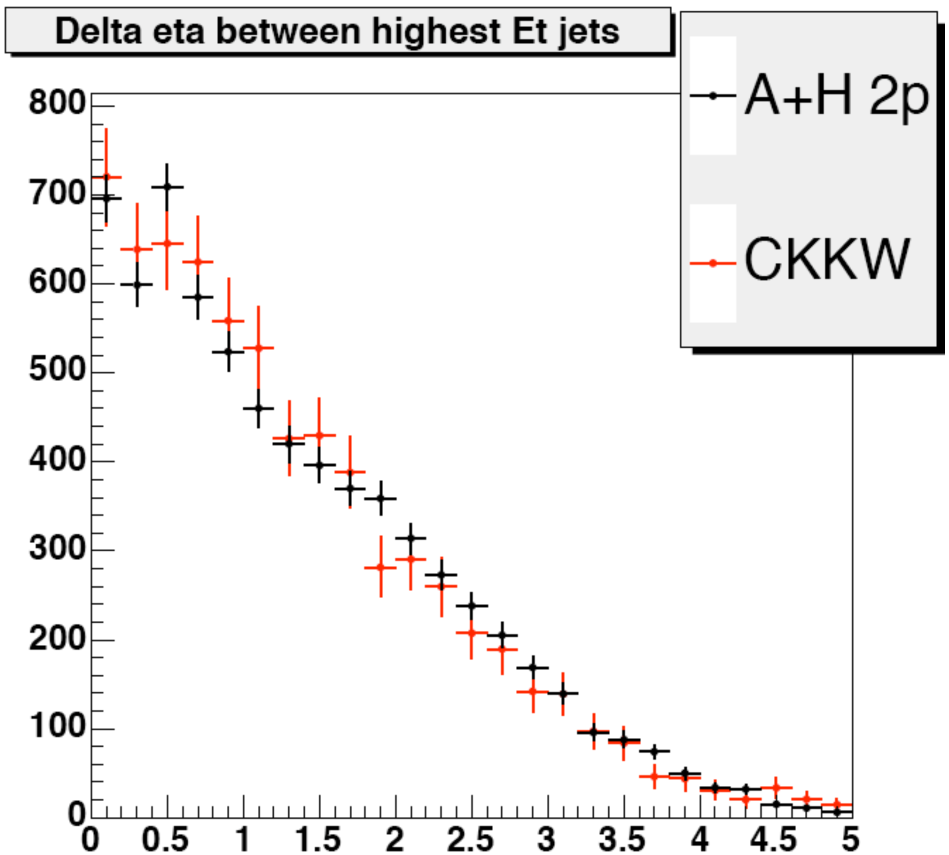
- CKKW decomposition

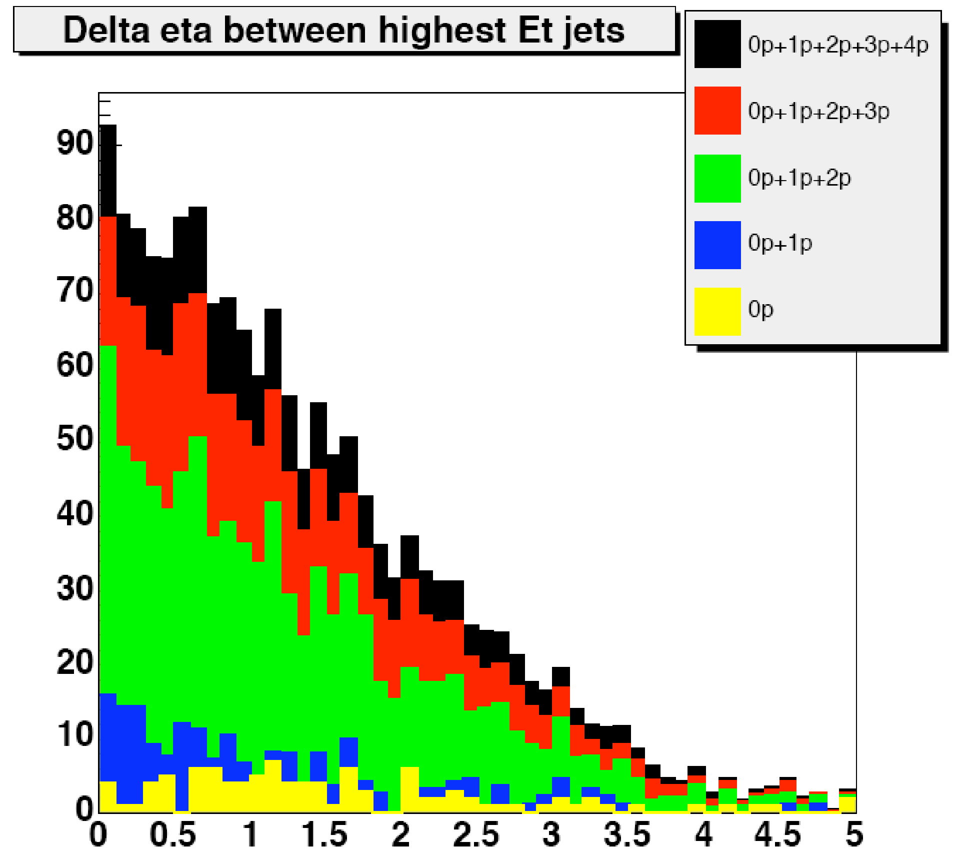




E_T of tag jets > 20 GeV/c

- CKKW decomposition



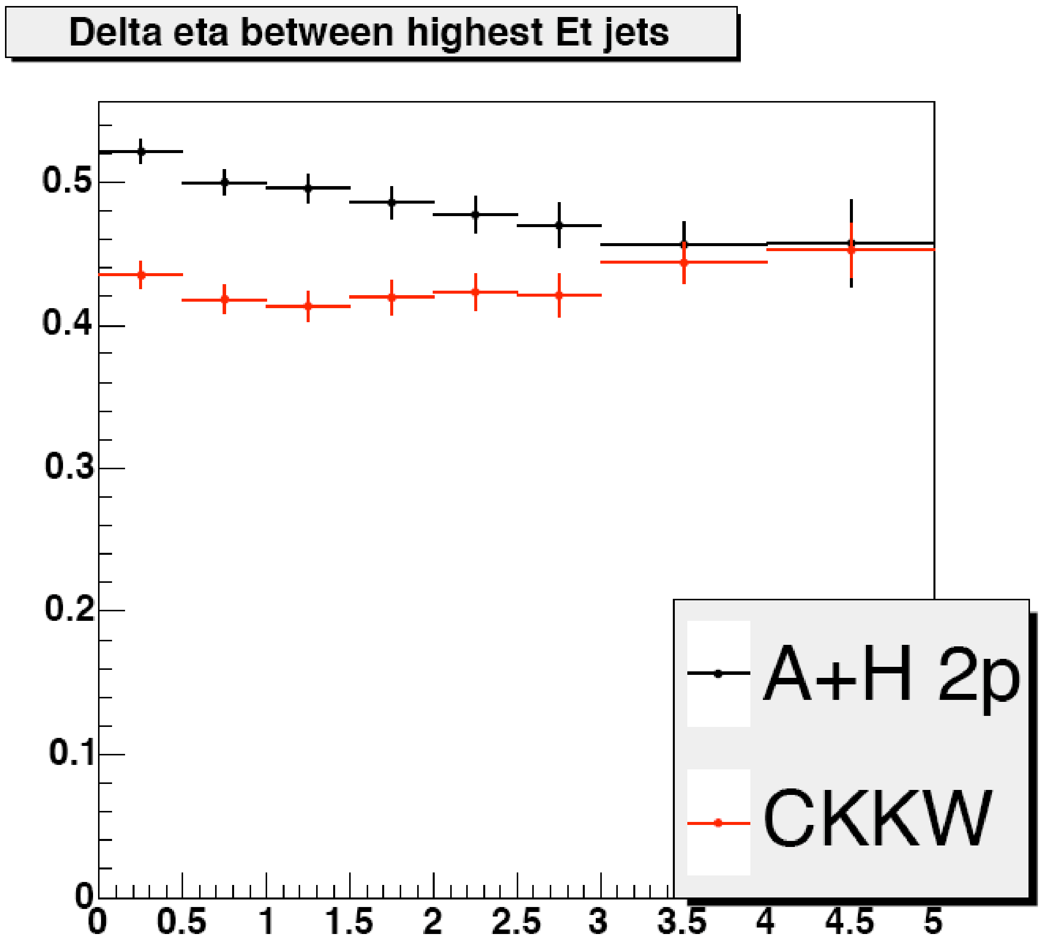


For low E_T tagging jets, W + 0 p relatively important; 2 p required for higher E_T

2 jet/>= 2 jet ratio as function of η

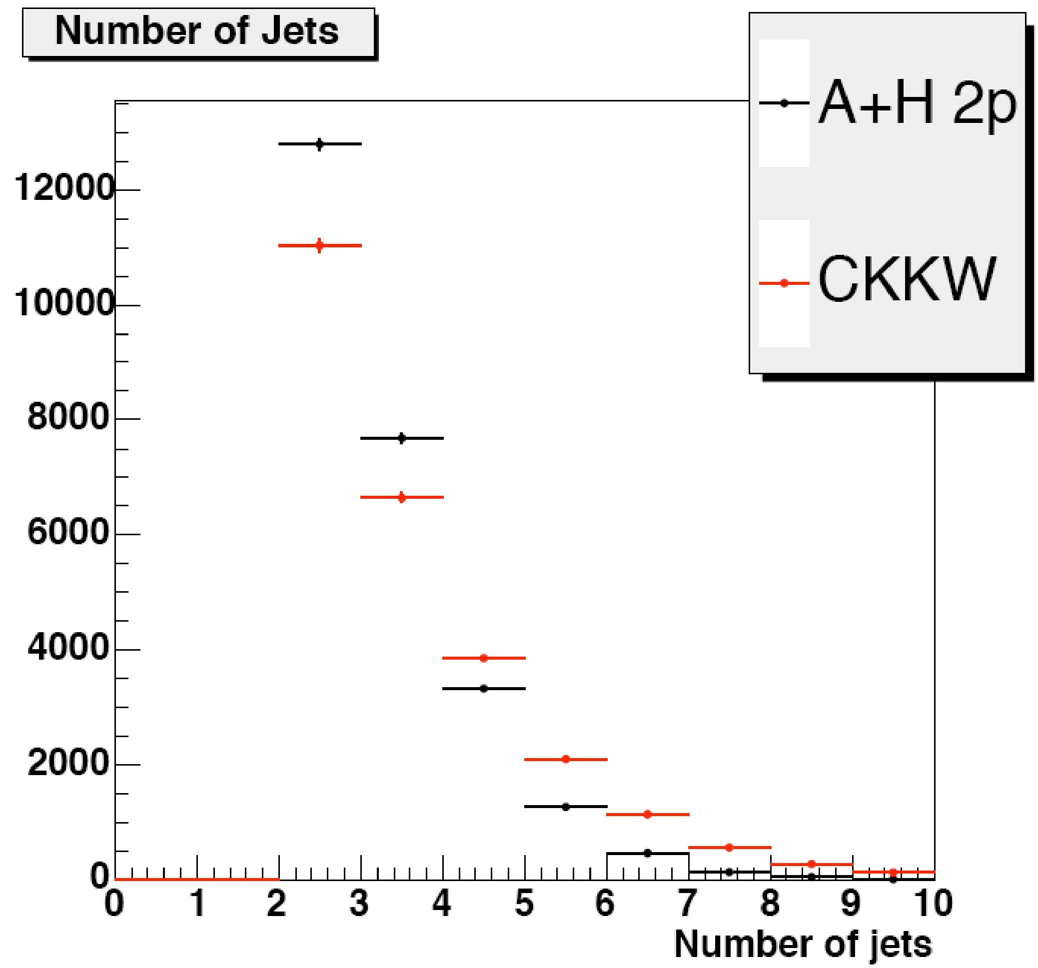
- Fraction of >= 2 jet events with only 2 jets
- 3rd jet has cut at 8 GeV/c; 3 different cuts on tagging jets

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



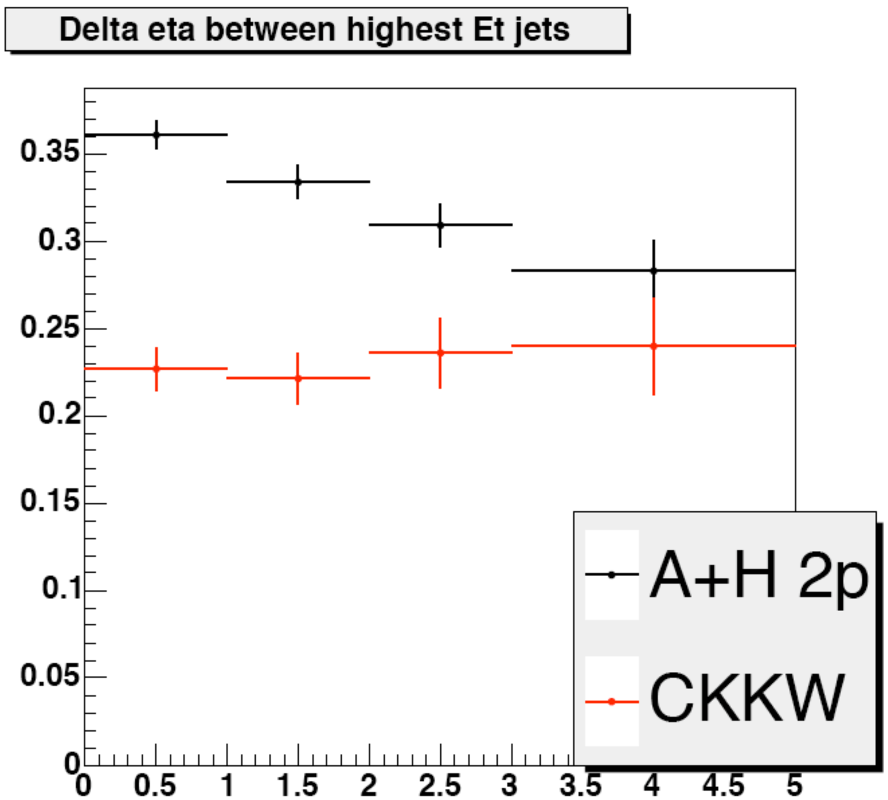
Jet multiplicity

- 8 GeV/c tagging jets (+central jet)
- All η separations

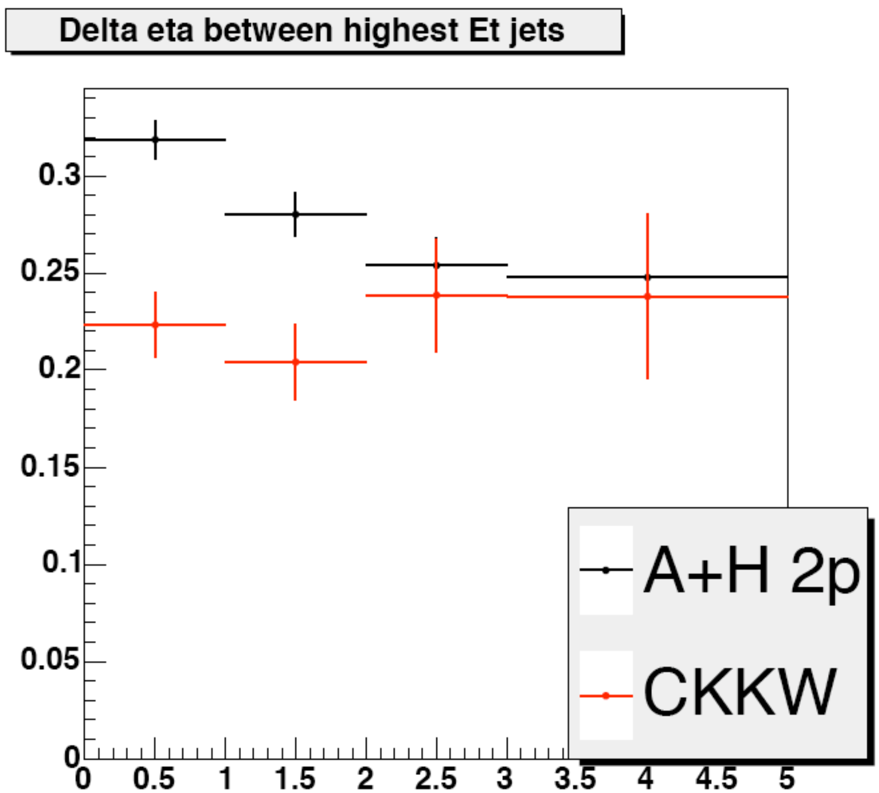


2 jet/>= 2 jet ratio as function of η

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



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

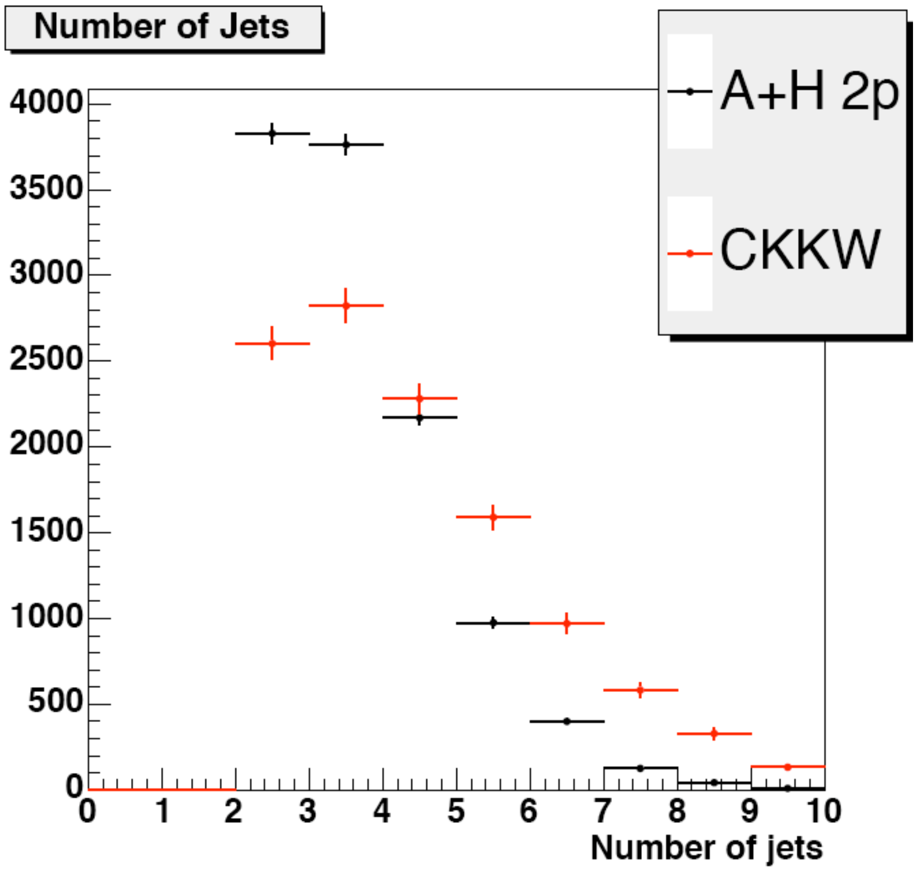


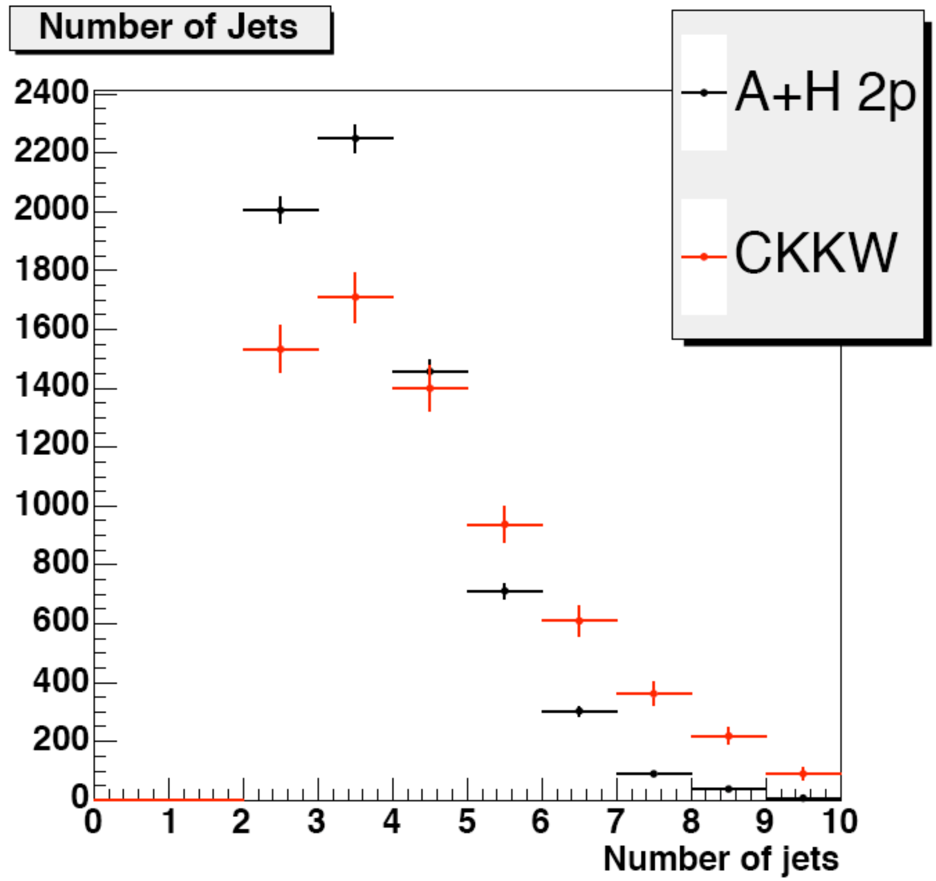
A+H predicts too high a rate; CKKW agrees well with the data; rate is flat with rapidity separation; note >= 3 jet fraction very high (~80%)

Jet multiplicity

- 15 GeV/c tagging jets (+ 8 GeV/c central jet)
- All η separations

- 20 GeV/c tagging jets (+ 8 GeV/c central jet)
- All η separations

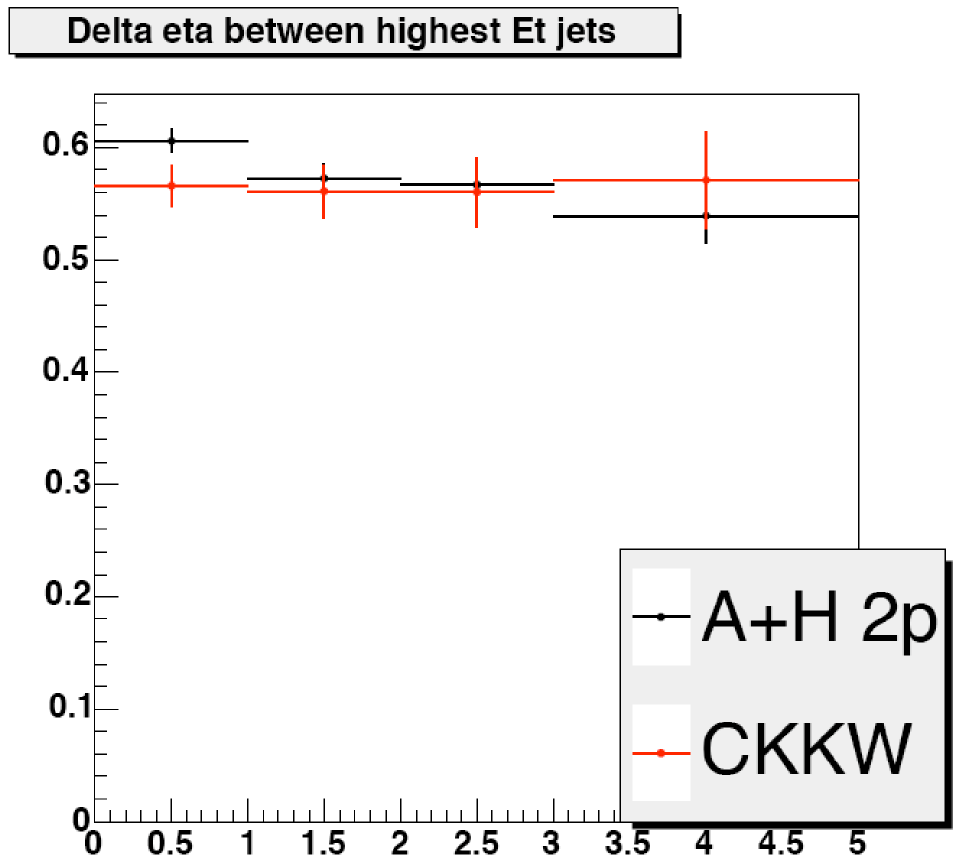




2 jet/>= 2 jet ratio as function of η

- 3rd jet probability decreases with increasing 3rd jet E_T cut

Tag jets > 15 GeV/c; 3rd jet > 12 GeV/c



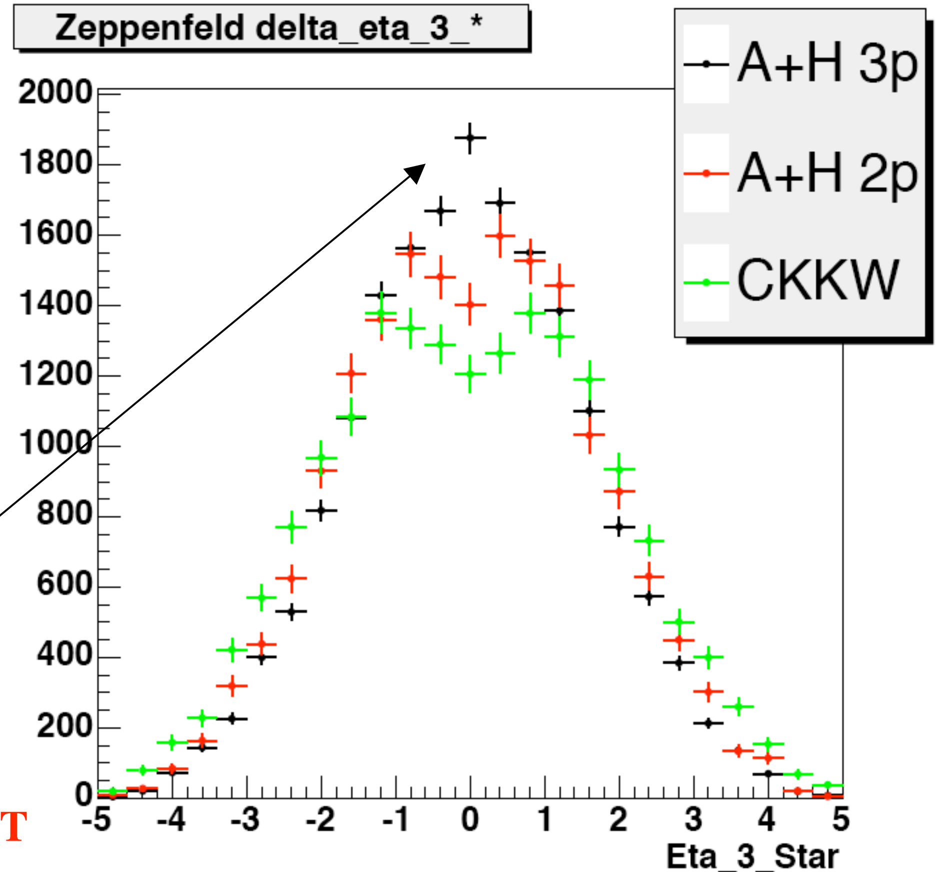
The Zeppenfeld plots*

*copyright
J. Huston
2004

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

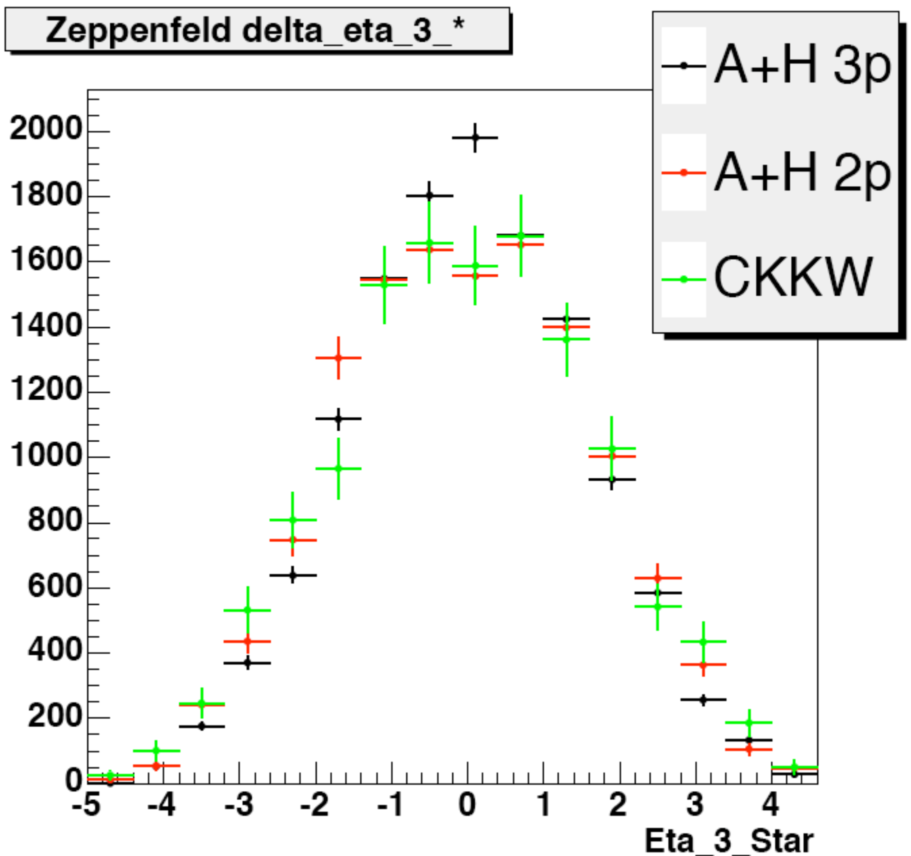
Tag jets > 8 GeV/c; 3rd jet > 8 GeV/c



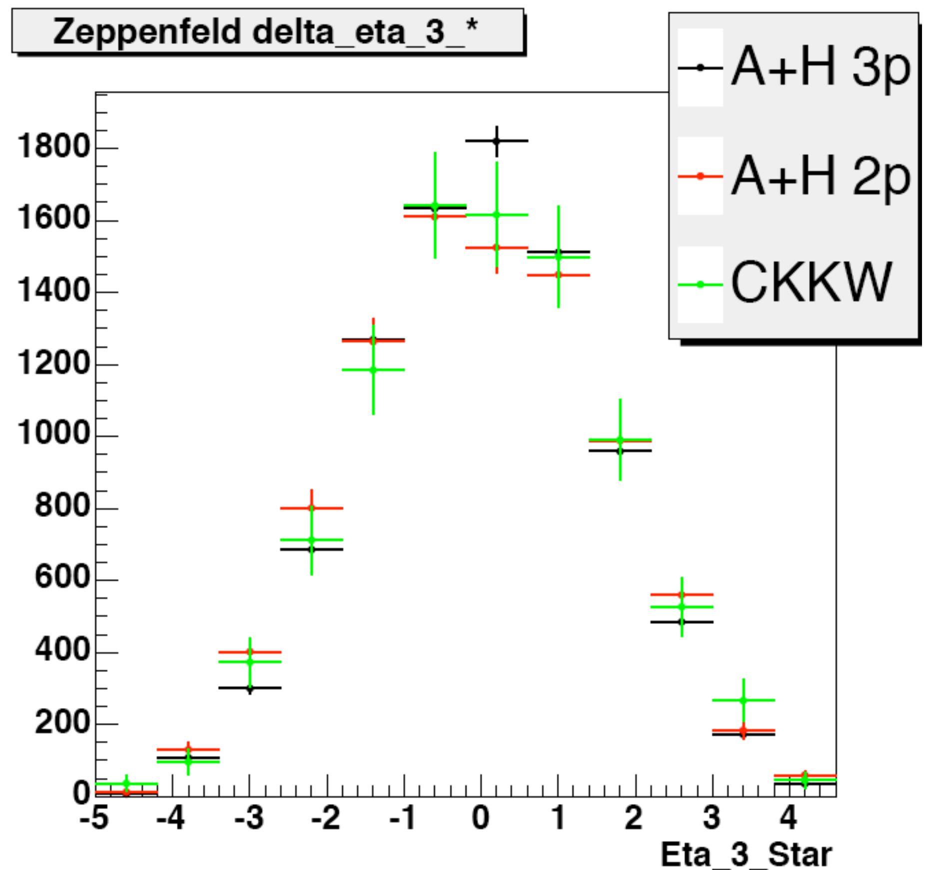
note peak for A+H 3p
…or dip for other distributions
data has dip **for low p_T**
CKKW has Sudakov suppression where ME does not

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

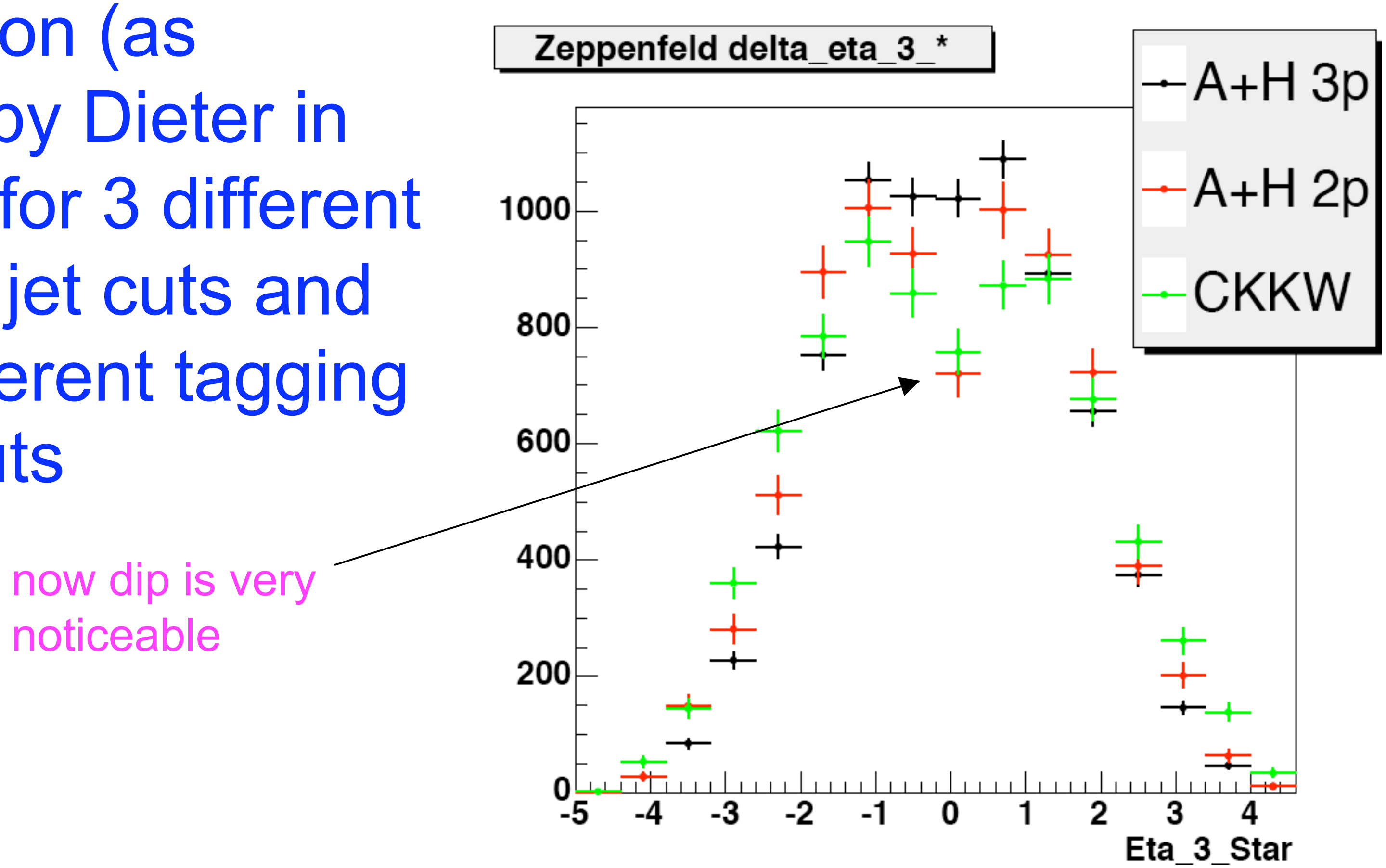


Dip fills in as tag jet E_T increases

η_3* for $\Delta\eta$>2

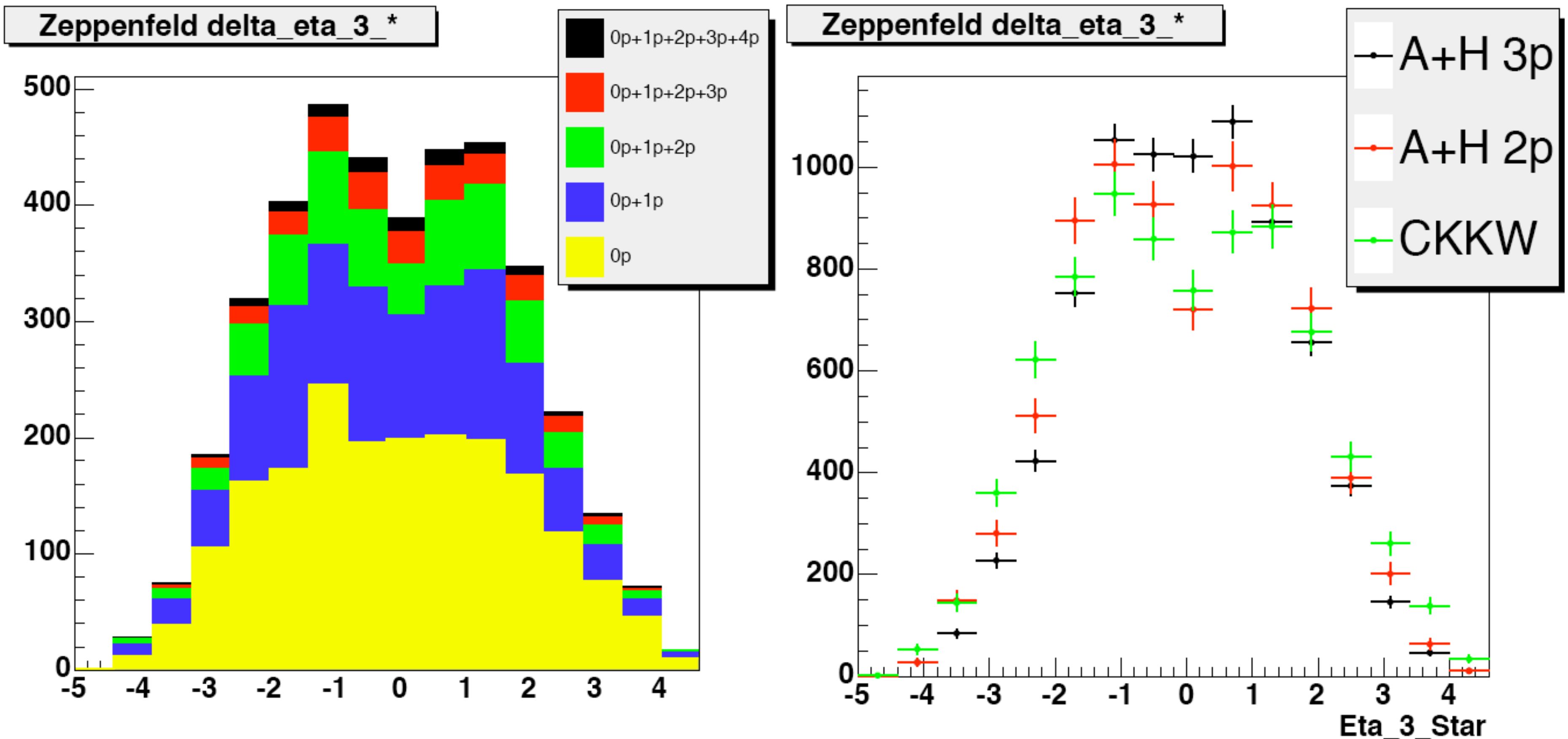
- Look at η_3* distribution (as defined by Dieter in his talk) for 3 different tagging jet cuts and for 3 different tagging jet $\Delta\eta$ cuts

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



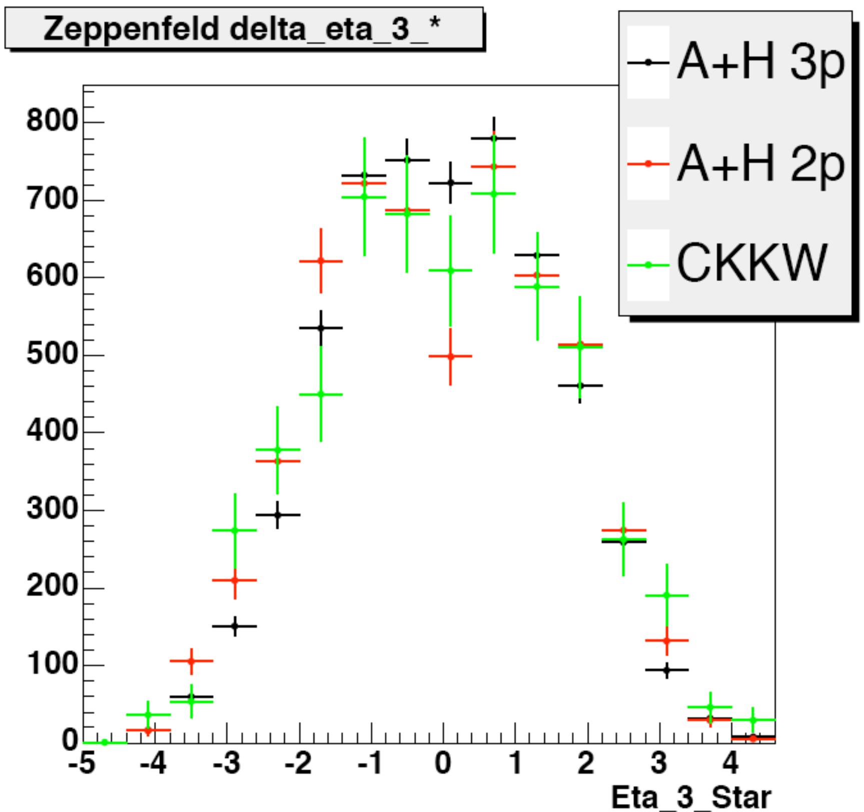
η_3^* for $\Delta\eta$>2: CKKW decomposition

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

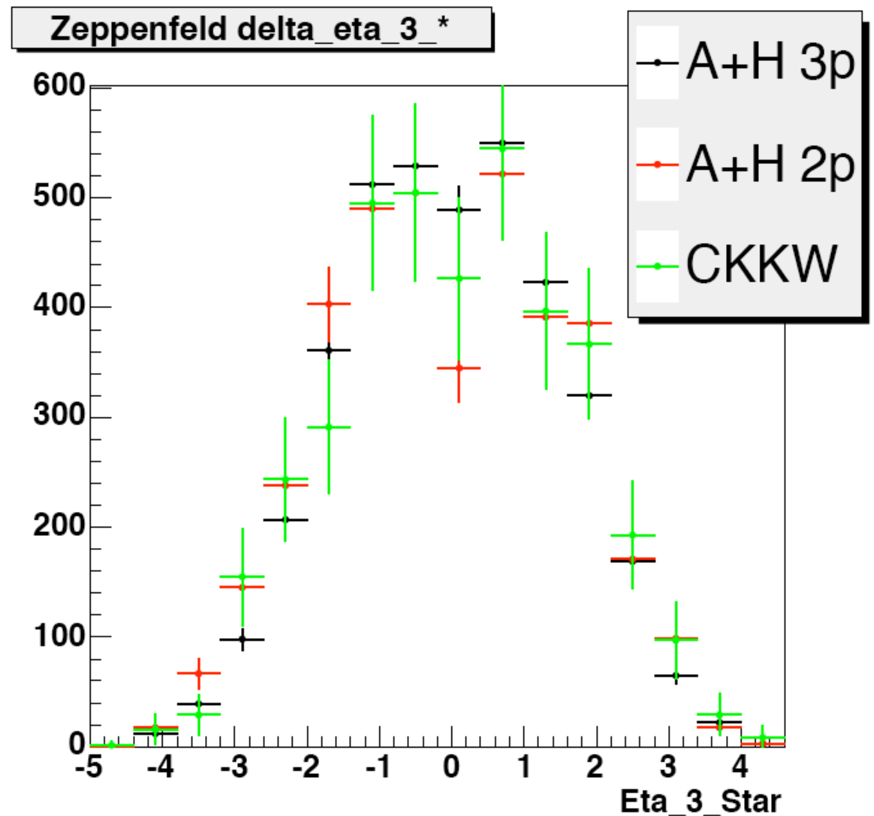


η_3* for $\Delta\eta$>2

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

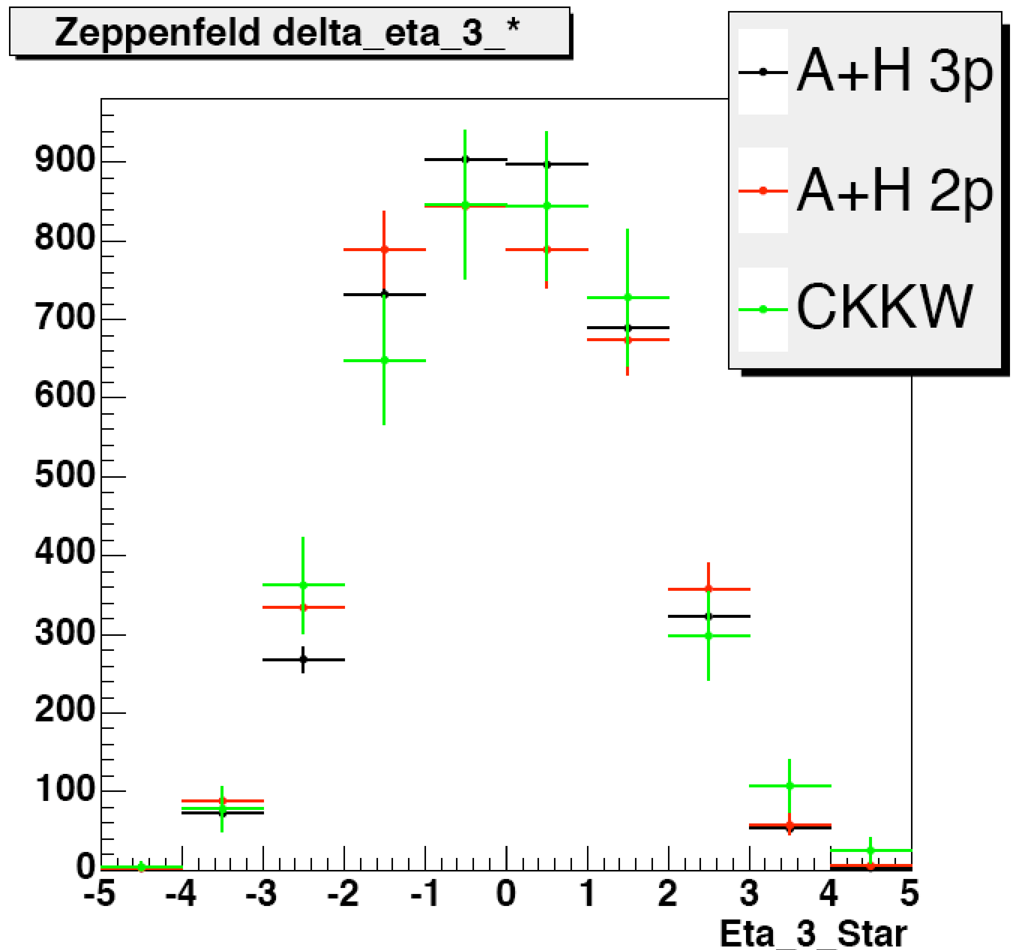


Tag jets > 20 GeV/c; 3rd jet > 8 GeV/c



η_3^* for $\Delta\eta>2$

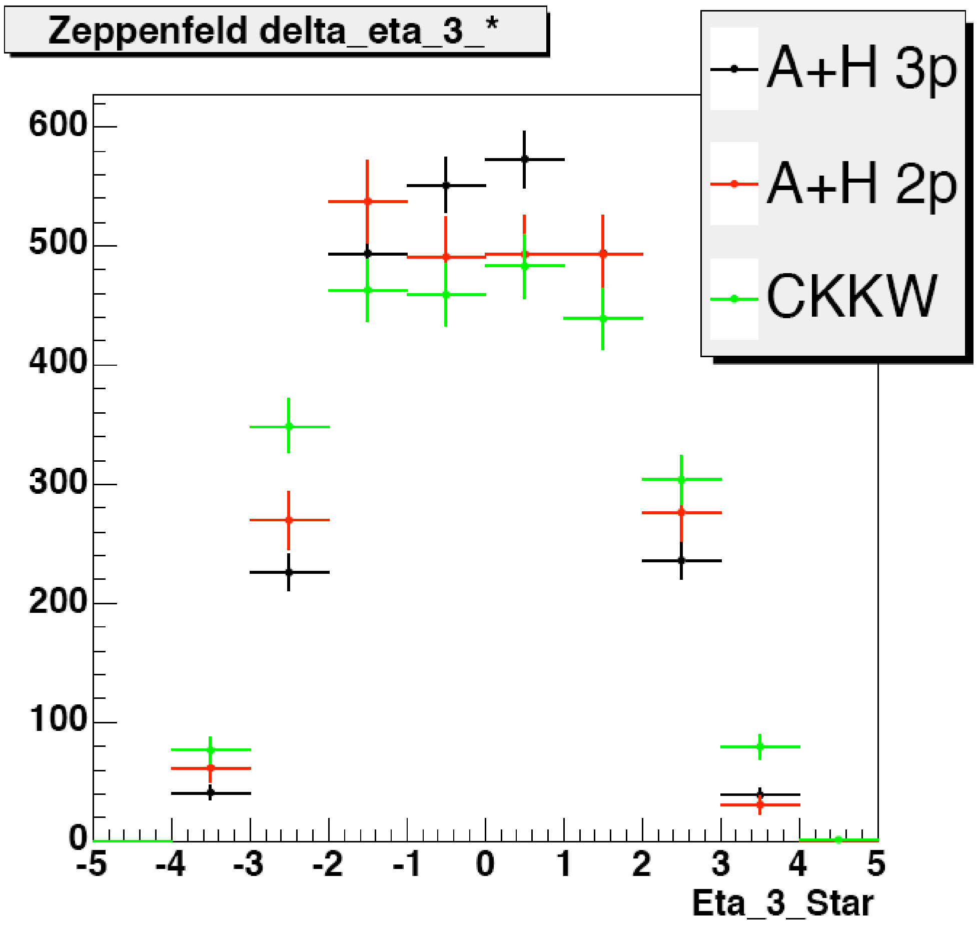
Tag jets > 15 GeV/c; 3rd jet > 12 GeV/c



η_3^* for $\Delta\eta>3$

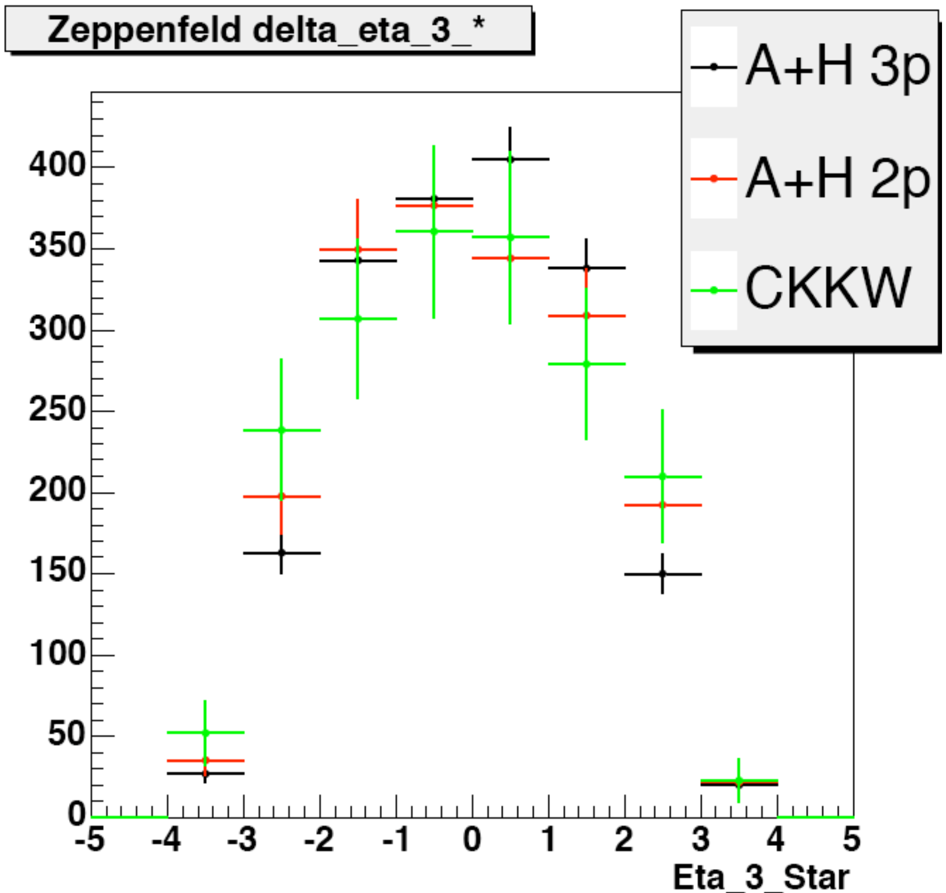
- Look at η_3^* distribution (as defined by Dieter in his talk) for 3 different tagging jet cuts and for 3 different tagging jet $\Delta\eta$ cuts

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

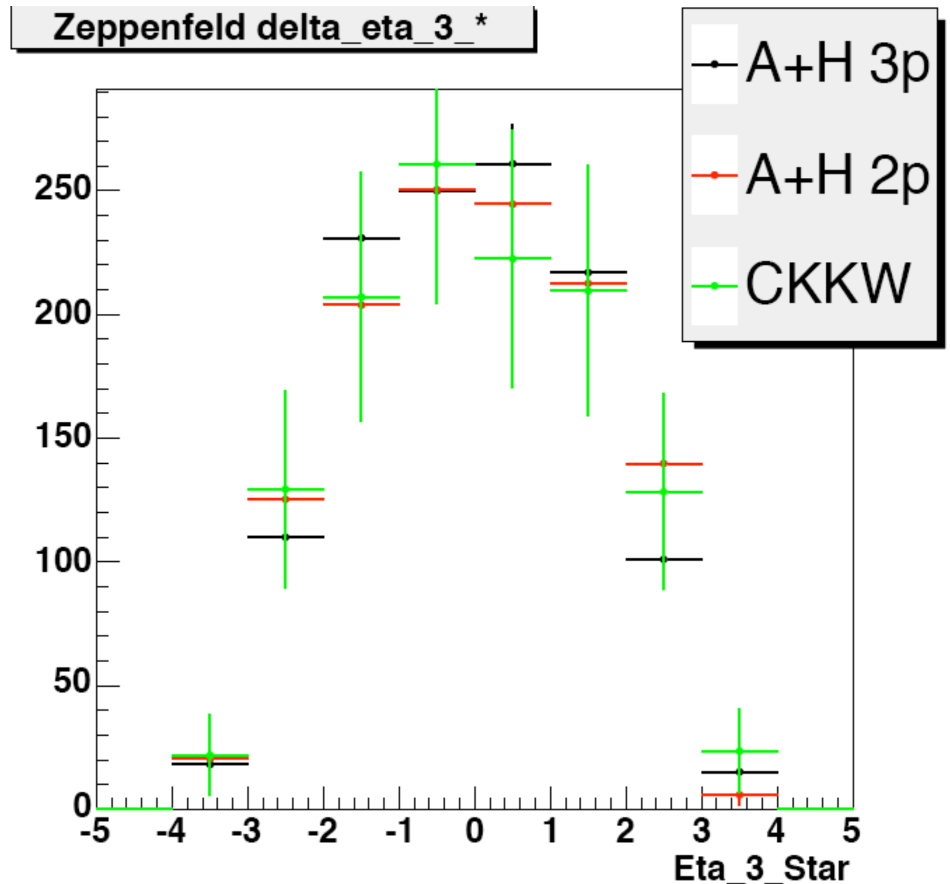


η_3^* for $\Delta\eta>3$

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



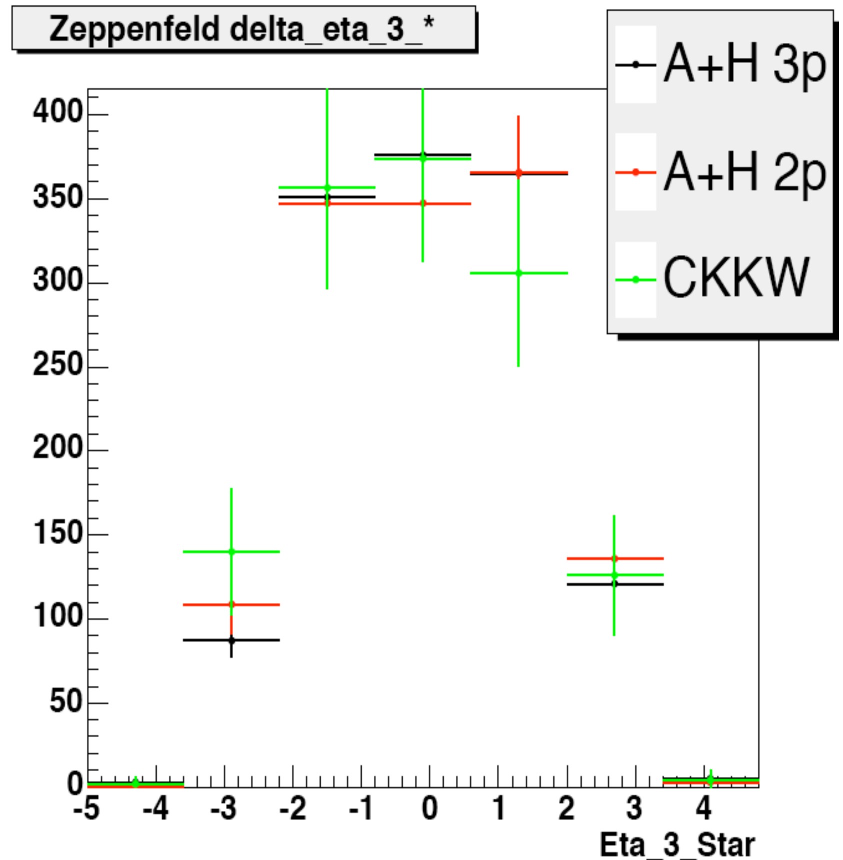
Tag jets > 20 GeV/c; 3rd jet > 8 GeV/c



η_3^* for $\Delta\eta>3$

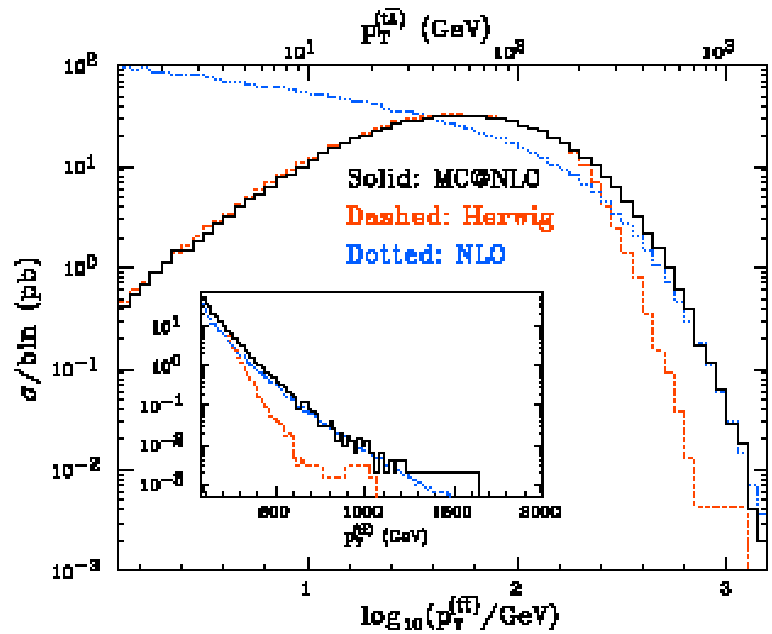
- Right now working hard on blessing data so comparisons of data to all plots shown on previous pages can be made public
- This summer
- Also working with Steve Mrenna and John Campbell on validation of CKKW results using MCFM
  - paper this summer

Tag jets > 15 GeV/c; 3rd jet > 12 GeV/c



MCatNLO

- Ideally, want NLO normalization and kinematics while retaining the effects of multiple gluon radiation and hadronization
- Many papers written on the subject
- MCatNLO (Frixione/Webber) is only program in use by experimenters
- Working model has new collaborators coming in to work on favorite process
  - Eric Laenen: single top production
  - Vittorio del Duca: WH and WW fusion to Higgs
  - Bill Kilgore and Steve Ellis: inclusive jet production

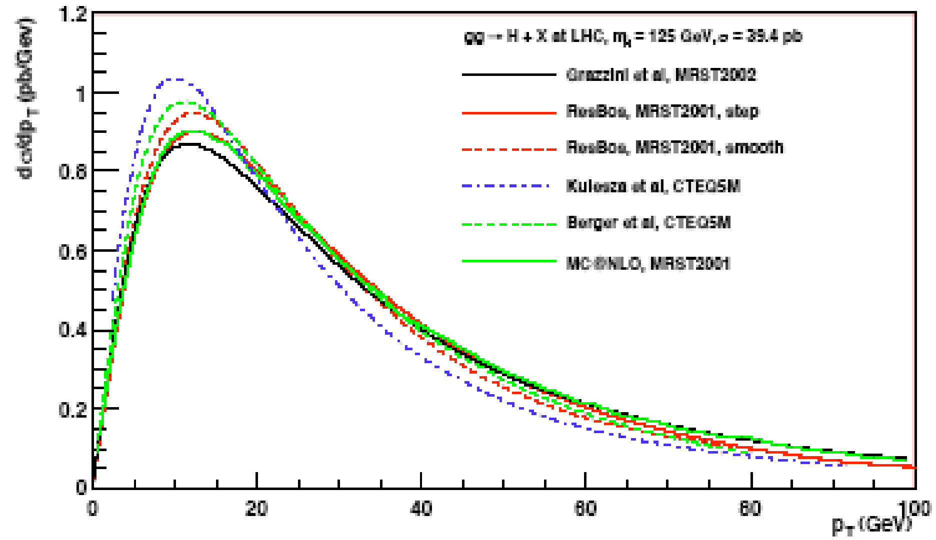


- Smoothly matches soft/collinear (MC) and hard (NLO) regions
- Available for $pp \to W, Z, H, \gamma^*, b\bar{b}, t\bar{t}, WW, ZZ, WZ$

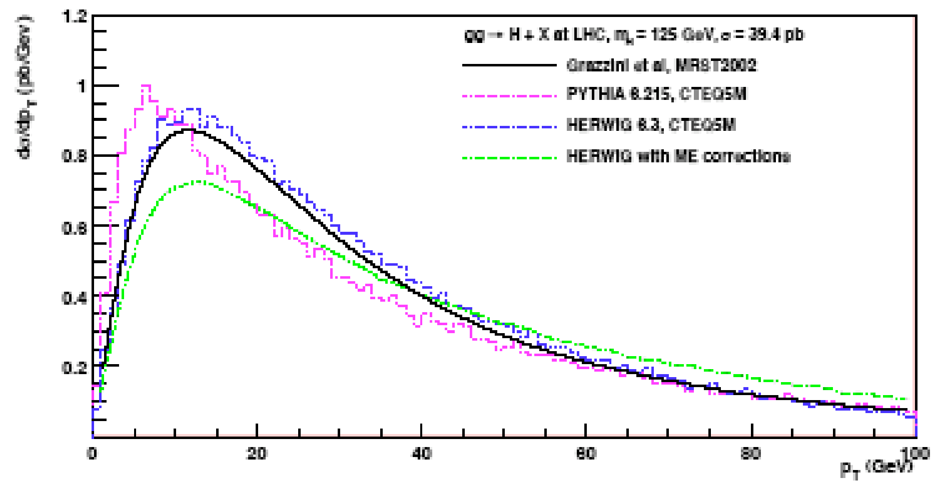
first session of Les Houches 2005 will concentrate on adding processes to MCatNLO

p_T distributions

- Effects of soft gluon radiation in the initial state result in non-zero p_T distributions for the final state
- Can describe by DGLAP resummation formalism (accurate to as much to NNLL) or by parton showers (almost NLL for the case of Herwig)
- Higgs production is a great testbed for effects of soft gluon radiation
  - gg initial state
  - lots of phase space for gluon radiation
- Shapes agree fairly well (resummation has NLO or NNLO normalization) but Pythia 6.2 peaks a bit lower
  - p_T ordered shower in Pythia 6.3 in better agreement with resummation predictions



…a study from Les Houches 2003

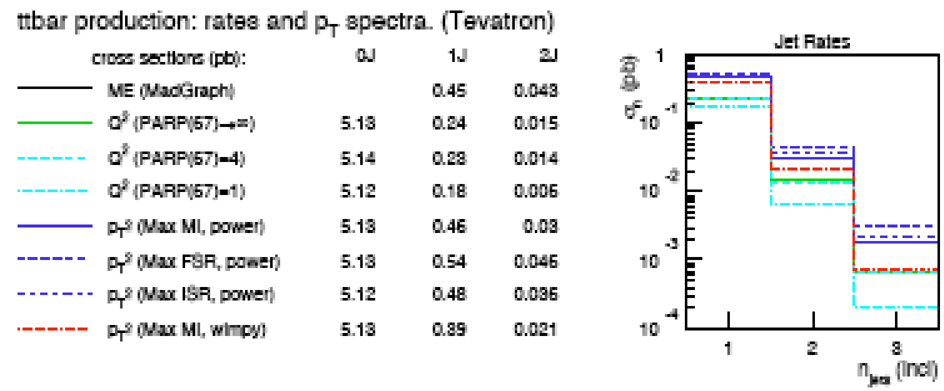


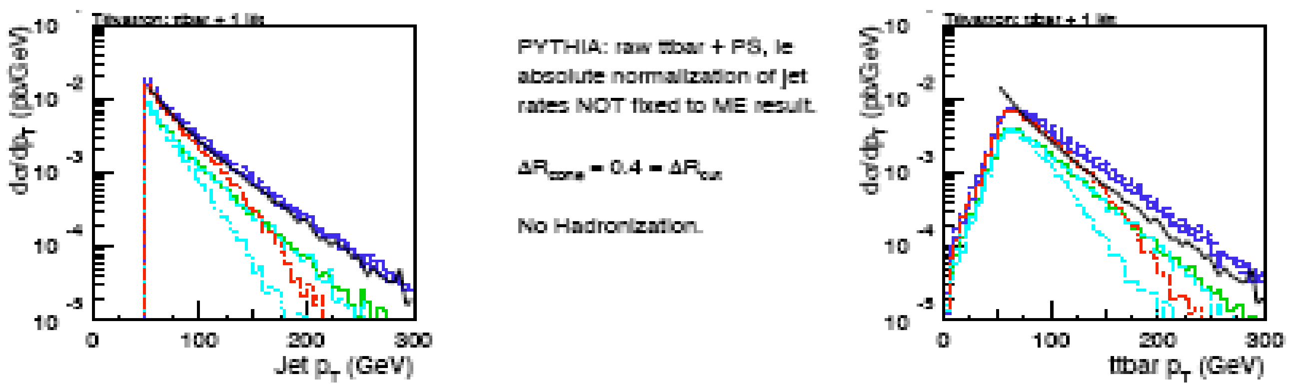
Les Houches 2005

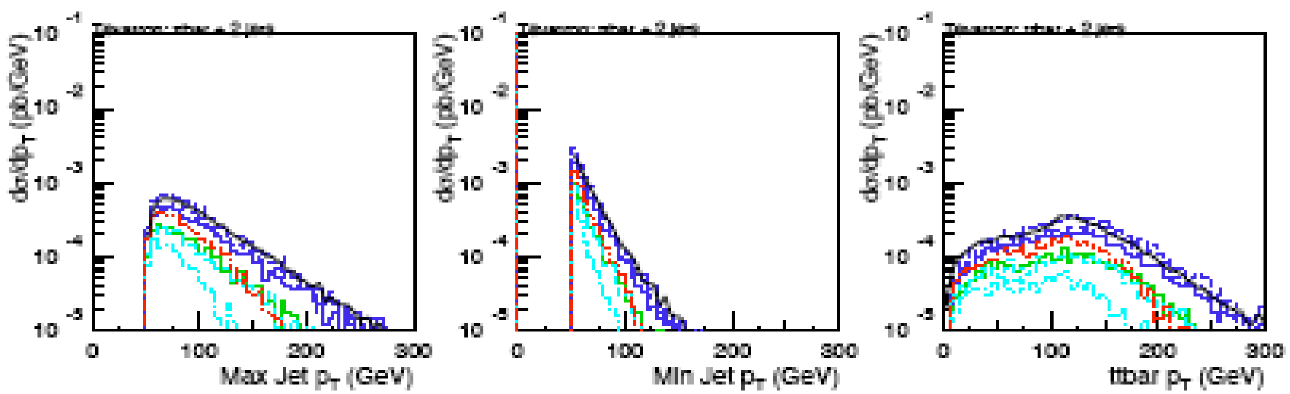
p_T-ordered shower in Pythia 6.3

- p_T-ordered shower in Pythia 6.3 leads to more robust predictions
- Parton shower agrees with ME predictions for t-tbar + 1 / 2 jets

plots produced by Peter Skands



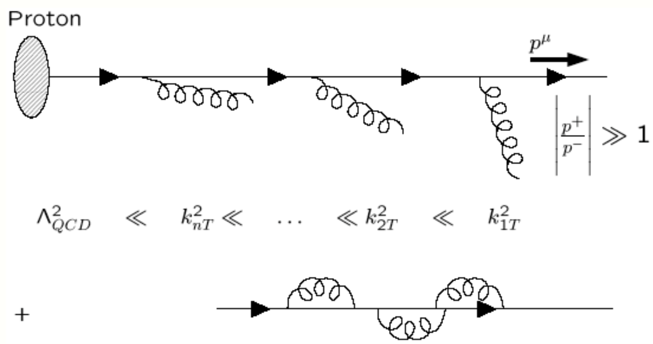




What if DGLAP factorization doesn't work

Pavel Nadolsky at Enrico Fermi symposium

Physics behind DGLAP factorization (cartoon)



Probed parton is highly boosted throughout all evolution

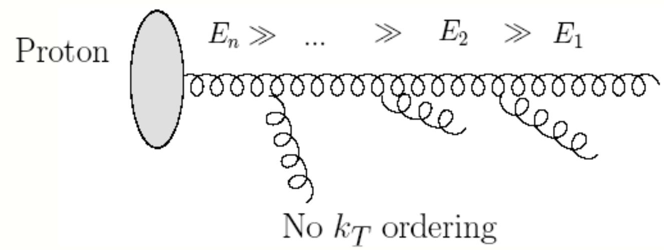
Soft and collinear radiation

- dominates parton evolution
- factorizes from the hard scattering
- is "collimated" ("k_T-ordered")

Angular distributions are described in a b-space resummation formalism

(Collins, Soper, Sterman, 1985)

The ultimate energy loss scenario (BFKL)



- The probed parton loses practically all energy through radiation
- The radiated partons do not have to be k_T-ordered
- Essential signature: broad angular distributions of the radiated hadrons

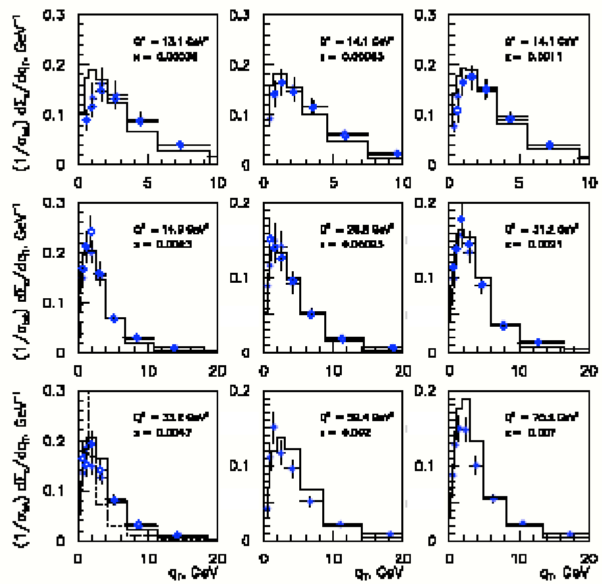
As x decreases, k_T-unordered dynamics may turn on faster in q_T distributions than in inclusive cross sections

[Compare $\alpha_S^n(Q)\ \ln^m(1/x)$ and $\alpha_S^n(1/b)\ \ln^m(1/x)$]

DGLAP resummation doesn't seem to work for SIDIS at HERA

q_T dependence of energy flow at small x

Data from *H1 Collaboration*



$13.1 < \langle Q^2 \rangle < 70.2 \quad \text{GeV}^2,$

$8 \times 10^{-5} < \langle x \rangle < 7 \times 10^{-3}$

Resummed E_T-flow: CTEQ5M1 PDFs,

$$S_{E_T}^{NP} = b^2 \left\{ 0.013 \frac{(1-x)^3}{x} + 0.19 \ln \left(\frac{Q}{2 \text{ GeV}} \right) \right\}$$

Possible interpretation:

rapid increase of "intrinsic" k_T when x decreases (first signs of k_T-unordered radiation???)

No mechanism for such increase in the $\mathcal{O}(\alpha_s)$ part of the CSS formula

Can be parametrized as

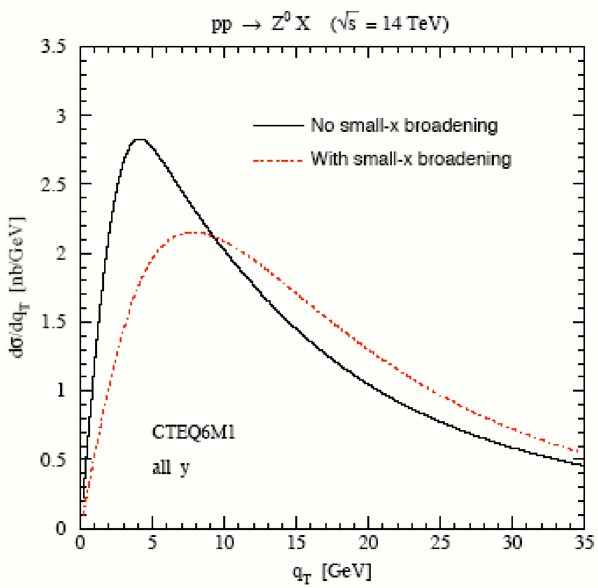
$$\overline{\mathcal{P}}(x,b) = (\mathcal{C} \otimes f)(x, b_*) e^{-\rho(x) b^2},$$

$$\rho(x) \approx \frac{0.013}{x} \text{ at } x \lesssim 10^{-2}$$

Impact at the LHC

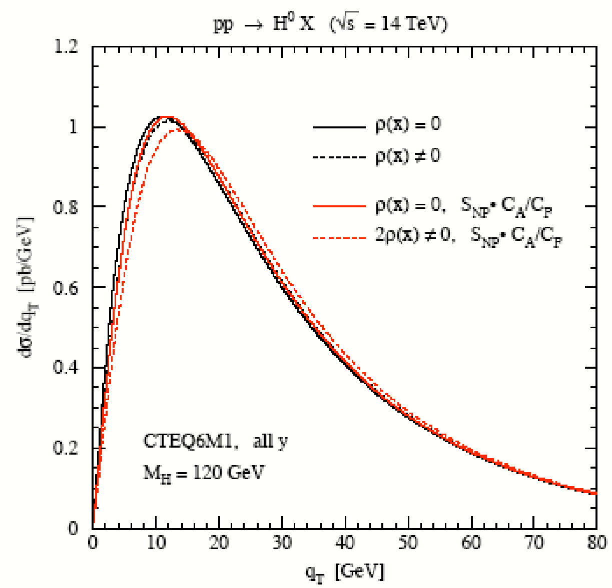
Pavel Nadolsky, EFI Mini-Symposium, U. of Chicago, March 14, 2005

Small-x effects at the LHC: visible even in the central region!



Z^0 production $(x|_{y\approx 0} \approx 0.007)$

Drastic differences



SM Higgs boson production Effects less pronounced due to (a) harder q_T spectrum and (b) narrower rapidity distribution

Broadening increases in magnitude as y grows

~~ATLAS~~ Les Houches benchmark studies

- Simulate events for some crucial Standard Model cross sections
  - for 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? Is our calorimeters correctly calibrated?
    - are we seeing signs of “unexpected” SM physics in our data?
    - how many of the signs of new physics that we observe can we believe?
  - feedback for impact of ATLAS data on reducing uncertainty on relevant pdf’s and theoretical predictions
  - venues for understanding some of the subtleties of physics issues

Updates/progress will appear on www.pa.msu.edu/~huston/Les_Houches_2005/Les_Houches_SM.html

Benchmark processes

- Inclusive jet cross section
  - $d\sigma/dp_T dy$
  - Δy: 0-1,1-2,2-3
  - p_T^{min}>180 GeV/c, 500 Gev/c, 1000 GeV/c, 1400 GeV/c to generate full spectrum
- Differential dijet production
  - $d\sigma/dp_{T1}d_{y1}dp_{T2}dy_2$
  - same events as above, different binning
- W/Z/Drell-Yan production
  - $d\sigma/dy$
  - A_{FB}
  - WW,W $\gamma(\gamma)$
  - W/Z + jets
- Single photon production
  - $d\sigma/dp_T dy$
- Underlying event
  - effects on above analyses

- Events will be produced with Pythia/Herwig using CTEQ6.1 pdf's
  - and some of error pdf's such as 29 and 31
  - if enough computing resources, will generate using more error pdf's
- Resulting cross sections will be weighted by a bin-by-bin NLO K-factor before being used as pseudo-experimental datasets in the CTEQ fitting package
- Most cross sections will be dominated by systematic errors and not statistical errors
  - some fraction of events need to go through full event simulation in order to understand
  - need to talk with jet group to fully understand correlated systematic errors

…essentially the same as the program that Samir has outlined in the morning; other suggestions/volunteers

Example: Inclusive jet cross section

- Current range of uncertainty for predictions for ATLAS

see hep-ph/0303013

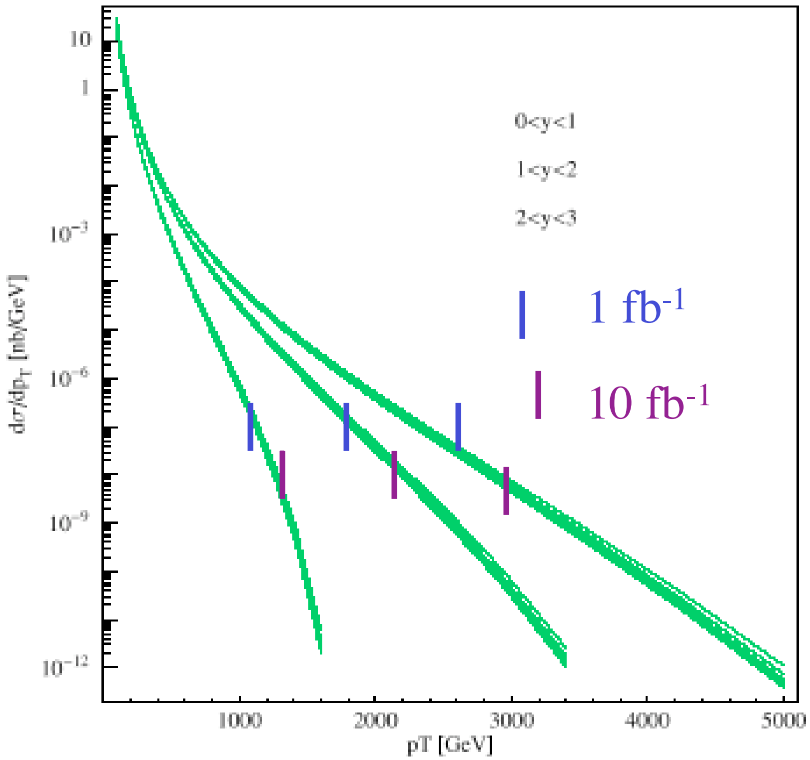


FIG. 30: The inclusive jet cross section as a function of p_T for three rapidity bins at the LHC. The three rapidity ranges are (0,1), (1,2) and (2,3). Predictions of all 40 eigenvector basis sets are superimposed.

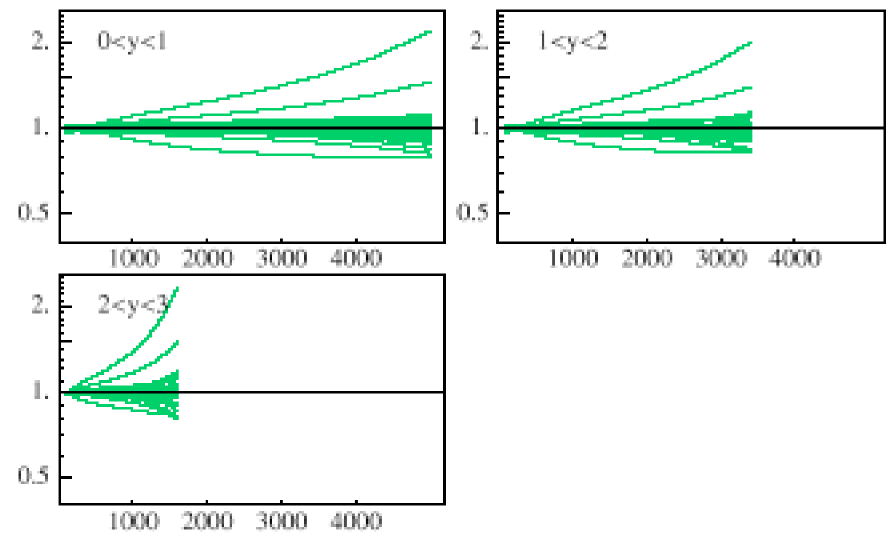


FIG. 31: The uncertainty range of the inclusive jet cross section at the LHC. The curves are graphs of the ratios of the cross sections for the 40 eigenvector basis sets compared to the central (CTEQ6.1M) prediction (ordinate) versus p_T in GeV (ordinate).

Will Run II Tevatron jet data be enough to reduce uncertainty? **TeV4LHC exercise**
What will pdf uncertainties look like at the end of HERA? **Related HERALHC exercise**

QCD ≠ SM

- In a recent paper (hep-ph/0503152), Stefano Moretti and Douglas Ross have shown large 1-loop weak corrections to the inclusive jet cross section at the Tevatron
- Up to 20% effect at the Tevatron
  - impact on pdf's and high x gluon?
- Effect goes as $\alpha_W \log^2(E_T^2/M_Z^2)$
  - may be substantially larger for high E_T jets at the LHC
- Other (unsuspected) areas where weak corrections are important?

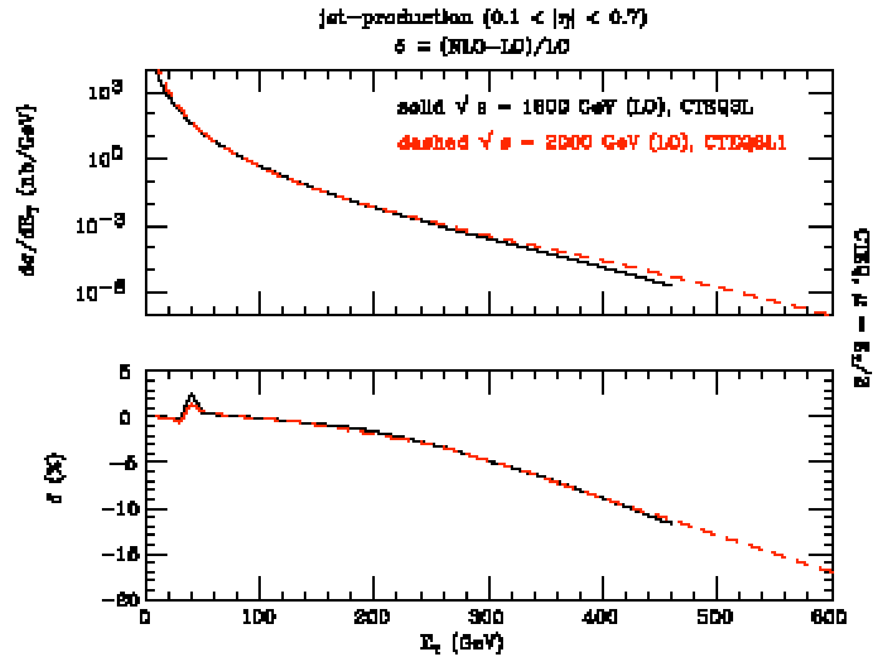


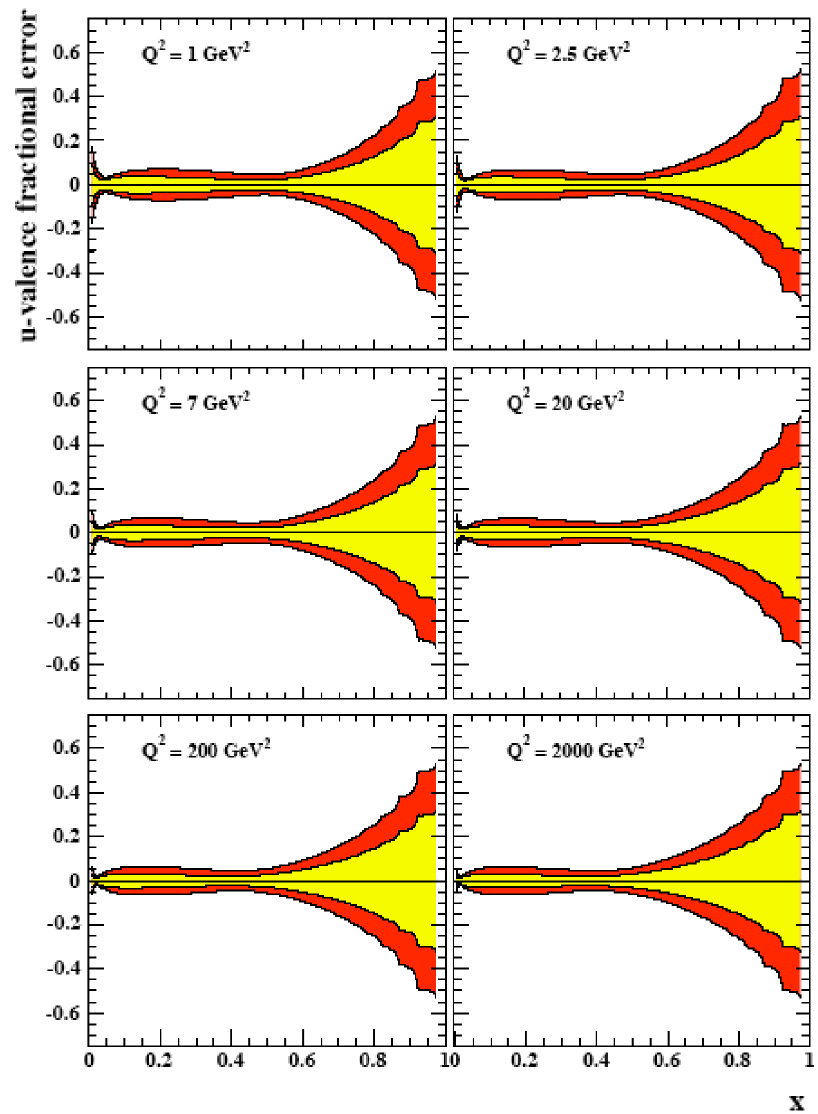
FIG. 1. The effects of the $\mathcal{O}(\alpha_S^2 \alpha_W)$ corrections relative to the LO results for the case of Run 1(Run 2) in the presence of PDFs preceding(following) the gluon re-parameterisation at medium/large Bjorken x, CTEQ3L(CTEQ6L1) [26]([21]). They are plotted as function of E_T for a choice of μ. The cut $0.1 < |\eta| < 0.7$ has been enforced, alongside the standard jet cone requirement $\Delta R > 0.7$.

Some other studies currently on-going at LHC and at Tevatron

- Hard scattering and hadronization
  - testing of matrix element-parton showering matching
    - CKKW (nominally part of Sherpa)
    - MLM
  - comparisons to NLO where available
    - *validation* of matching
  - studies with MCatNLO
    - and incorporation of inclusive jet production in MCatNLO, with Steve Ellis and Bill Kilgore
  - testing new parton shower approaches
    - Pythia 6.3 will give different predictions than earlier versions
  - underlying event tunes and model development
    - is Tune A universal? Can Tune A be improved?
    - can Jimmy be tuned to Tevatron? Can we get a better name for Jimmy?
    - extrapolations to LHC; can we provide a reasonable range?
  - hadronization corrections

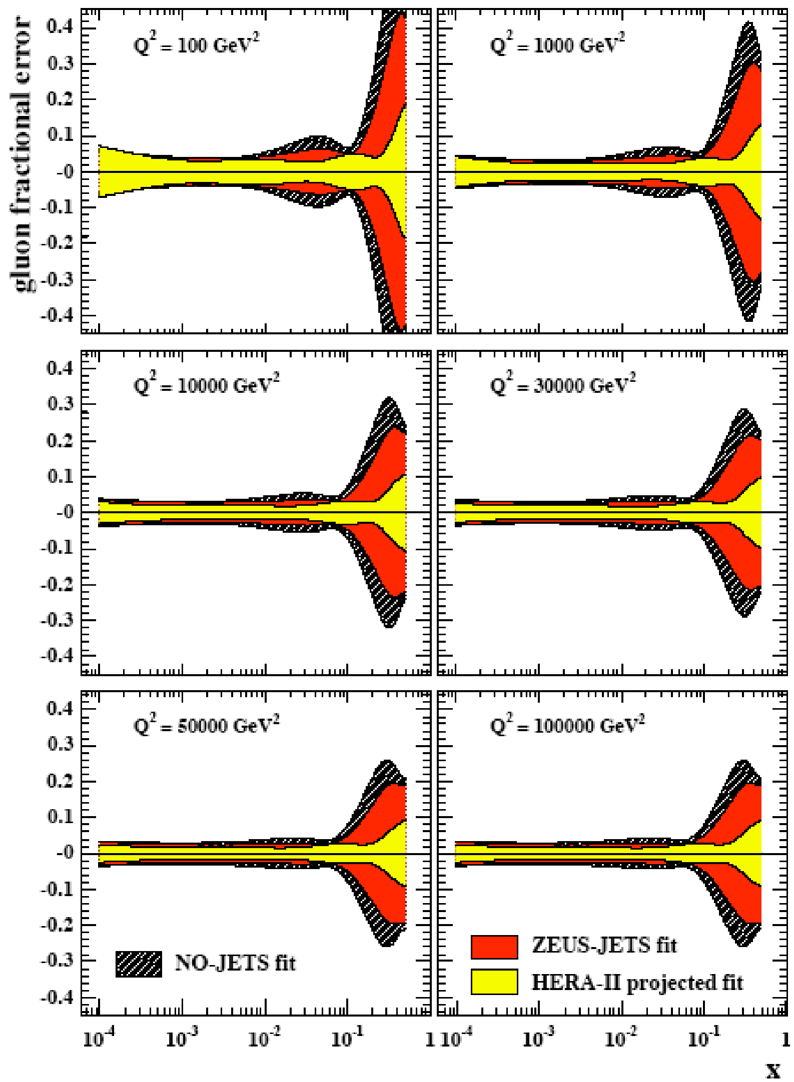
ZEUS pdf exercise

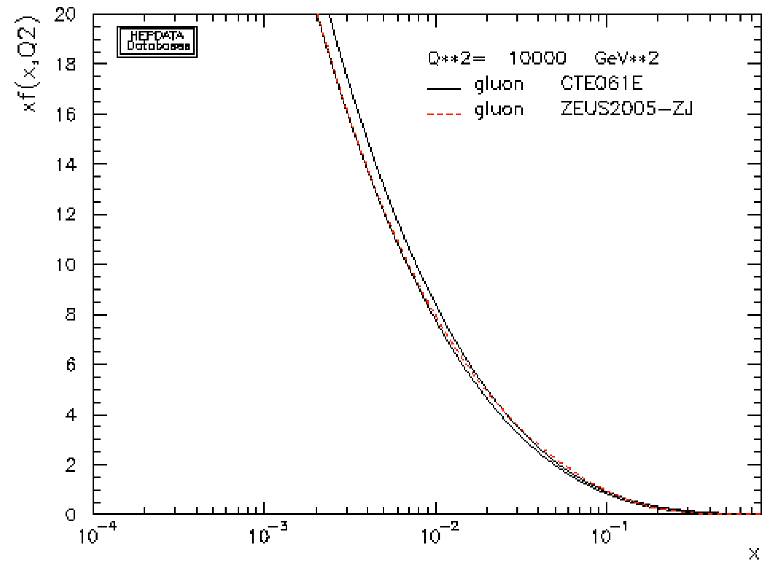
- Clare Gwenlan and Mandy Cooper-Sarkar
- Extrapolate ZEUS fitter uncertainties to statistics of HERA II
- Datasets also can be used with CTEQ fits?

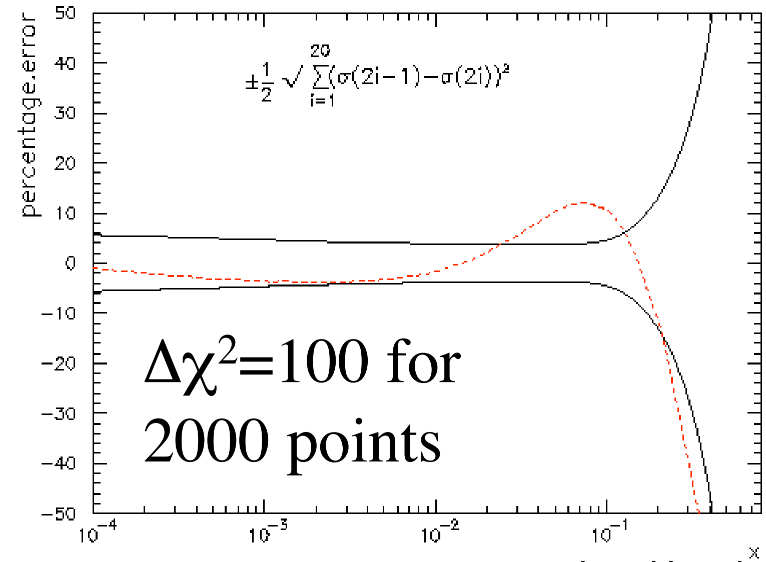


ZEUS exercise

$\Delta\chi^2$ of ~50 out of 600 points







$\Delta\chi^2$=100 for 2000 points

TeV4LHC

- TeV4LHC: conferences.fnal.gov/tev4lhc/
- QCD
  - www.pa.msu.edu/~huston/tev4lhc/wg.htm
  - all of the issues I talked about today are there
- TopEW
  - www.hep.anl.gov/tait/tev4lhc/topew.html
- Higgs
  - www-clued0.fnal.gov/~iashvili/TeV4LHC_higgs/higgs.html
- Landscape

- Next meeting will be at CERN April 28-30, 2005
- Final meeting at Fermilab in the fall of 2005

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.

Appendix A: some TeV4LHC projects

This list can also be found at

www.pa.msu.edu/~huston/tev4lhc/wg.htm

Jet projects

1. inclusion of jet production in MC@NLO

2. jet algorithms at the Tevatron and LHC

   -impact of negative towers: to remove or not to remove, the D0 experience
   -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 pT top
   -understanding differences observed in jet reconstruction between CDF and D0 environments
     -reconstruct sample of MC events that produce problems in the CDF environment
   -utility of new algorithms such as JEF for final state reconstruction

3. UE subtraction

   -definition of UE + uncertainty for comparisons of data to NLO
   -impact of ISR on jets and jet predictions
   -operation in high multiple interaction environment

PDF projects

1. validity of NLO formalism/road to NNLO

2. benchmarks for NLO/NNLO fits

3. pdf uncertainties
   -universal delta_chisquare
   -pdf weighting; impact of Sudakov FF's
   -embedding LHAPDF into programs

4. inclusion of Tevatron data in global fits
   -"back-of-the-envelope" studies
     -W+c
     -gamma +b/c
     -Z+b

5. W as a benchmark at both Tevatron and LHC

6. heavy flavor pdf's and their uncertainties

Projects, continued…

ME/MC projects

1. W + jets comparisons at the Tevatron->predictions for the LHC
   - -NLO->MCFM
   - -CKKW
     - -Mrenna
     - -Sherpa
   - -backgrounds to WW->H, the "Zeppenfeld plots"
   - -jet shapes/comparisons to CKKW

2. parton shower/resummation
   - -predictions for tt, Higgs
     - -impact of new parton shower algorithms

UE/hadronization projects

1. UE tunes for Tevatron->predictions for LHC
   - -understanding color re-connections and their apparent promiscuity
   - -can we reproduce Tune A in the more modern MC's
     - -Pythia 6.3
     - -Jimmy

2. hadronization corrections for NLO processes

3. ISR/UE corrections->subtractions for NLO

4. understanding high interaction multiplicity environment