TeV4LHC Workshop

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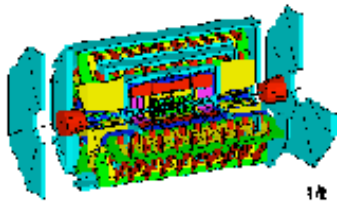
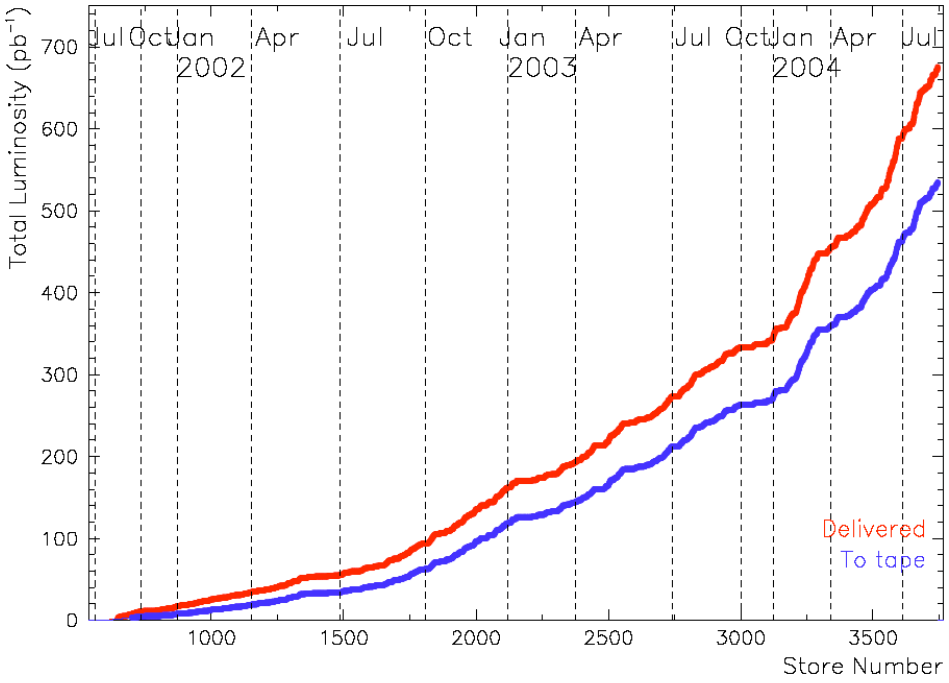
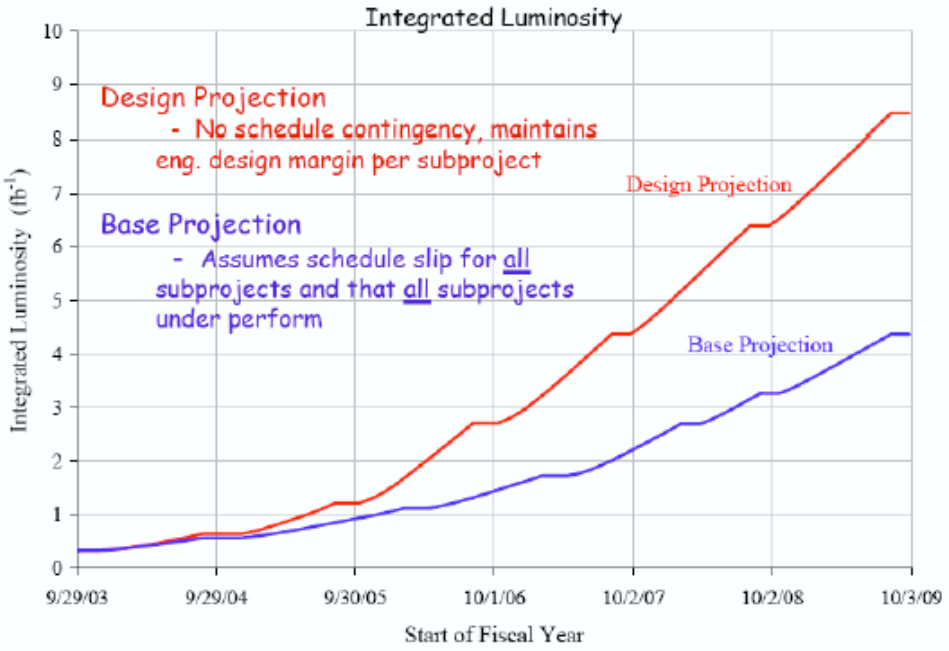


Tevatron Performance

~400 pb^{-1} available for analysis

ultimately 4-9 fb^{-1}





…currently in the middle of a shutdown for upgrades

Now onto TeV4LHC

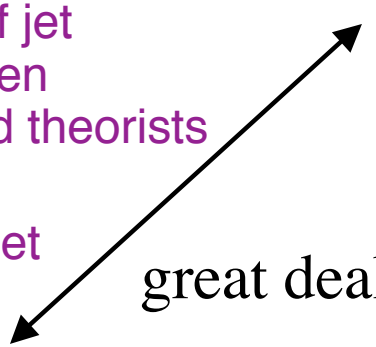
- First meeting Sept. 16-18

  The purpose of the workshop is to bring together the Tevatron and LHC experimental groups and the theoretical community to make the best possible use of data and experience from the Tevatron in preparing for the LHC experimental program. This will include understanding how to use Tevatron data to improve event modelling and theoretical understanding of cross sections for the signals and backgrounds at LHC, and also how to use experience with real problems at the Tevatron to best prepare for the challenges of doing analysis at the LHC.

- Physics groups
  - QCD
    - pdf's and event classifcation
    - hard scattering and hadronization
  - Top and electroweak
  - Higgs
  - Physics landscape

Physics group goals

- QCD
  - 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



great deal of overlap

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

Physics groups goals

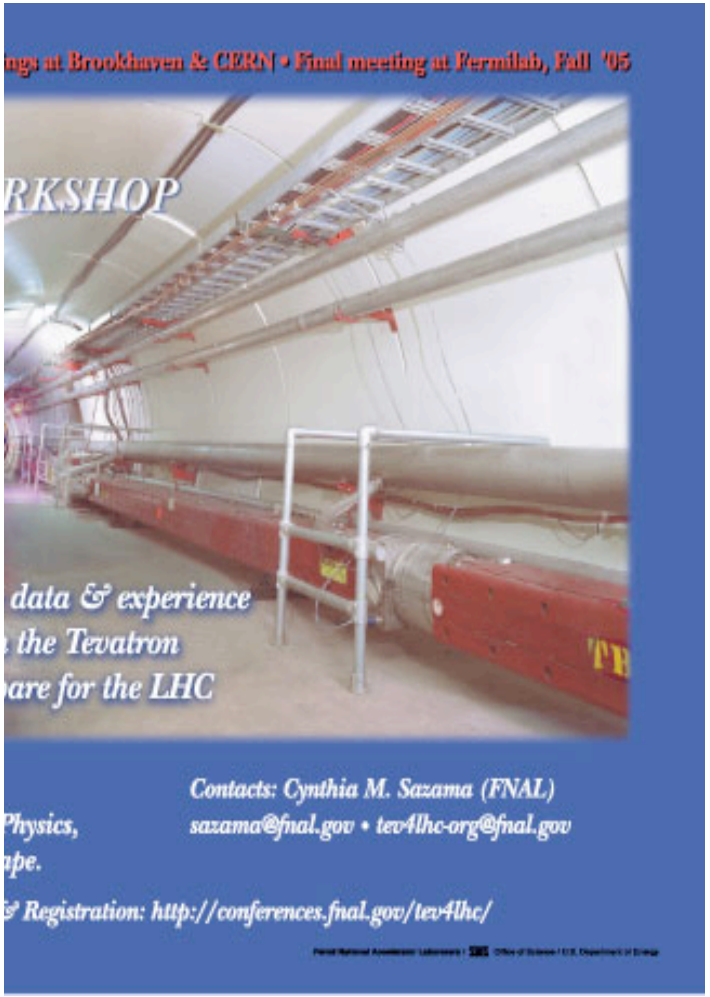
- Higgs
  - Wh, Zh with h->bb: can we use what we have learned at the Tevatron to make these modes more easily accessible at the LHC?
  - **b-tagging: what have we learned at the Tevatron about tagging b's/apply to LHC**
  - bb invariant mass resolution: how can we use our experience at the Tevatron to improve this at the LHC?
  - associated production of Higgs and tt~: can we use our experience with top at the Tevatron to optimize this at the LHC?
  - associated production of SUSY Higgs and b's (at large tan beta):
  - **vector-boson fusion: what have we learned about forward jets that can help us tag vector-boson-fusion processes at the LHC?**
  - **Higgs decay to two photons: what have we learned about photons at the Tevatron that can help us at the LHC?**
  - Higgs decay to WW-> leptons: can the Tevatron search help us optimize this at the LHC?
  - Higgs decay to tau's: what have we learned about taus at the Tevatron?
  - advanced analysis techniques - how can our experience at the Tevatron be used for Higgs at the LHC?
  - **theory: what calculations can we do to improve our predictions of signals and backgrounds at the Tevatron/LHC, as well as to improve our modeling?**
  - are there signals for standard model and non-standard Higgs that we have overlooked?

Physics group goals

- Physics landscape
  - how do the solutions to analysis problems for searches at the Tevatron generalize to the LHC?
    - are current Tevatron background techniques adequate for the LHC?
    - can new analysis ideas (NN, specialized jet reconstruction, energy flow) be employed at the LHC?
    - how about pure signature-based searches?
  - how will measurements and searches at the Tevatron impact theoretical predictions for the LHC?
    - impact of searches for Z-primes and W-primes?
    - constraints from SUSY searches_impact of better measurements of Mtop and MW?
    - how are the Tevatron and the LHC complementary?

TeV4LHC goals

- First of all, this is also a TeV4TeV workshop
- Essentially everything we're doing is useful/necessary for understanding and exploiting the Tevatron Run II data



TeV4LHC goals

- But of course, what we learn at the Tevatron is also useful for the LHC
  - the Tevatron is the only place to gain hands-on experience in hadron-hadron collider physics
- And the LHC experimenters is us
  - we can get credit for the LHC doing what we need for the Tevatron
  - I assume that's one of the reasons for 250 registrants

Conveners

- QCD (2 subgroups)
  - F. Chlebana, S. Ellis, W. Giele, J. Huston, W. Kilgore, S. Mrenna, W-K. Tung, M. Wobisch, M. Zielinski
- Top/EW
  - C. Gerber, T. Tait, E. Thomson, D. Wackeroth
- Higgs
  - A. Dominguez, I. Iashvili, S. Willenbrock
- Physics Landscape
  - R. Demina, B. Dobrescu, D. Rainwater, M. Schmitt

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

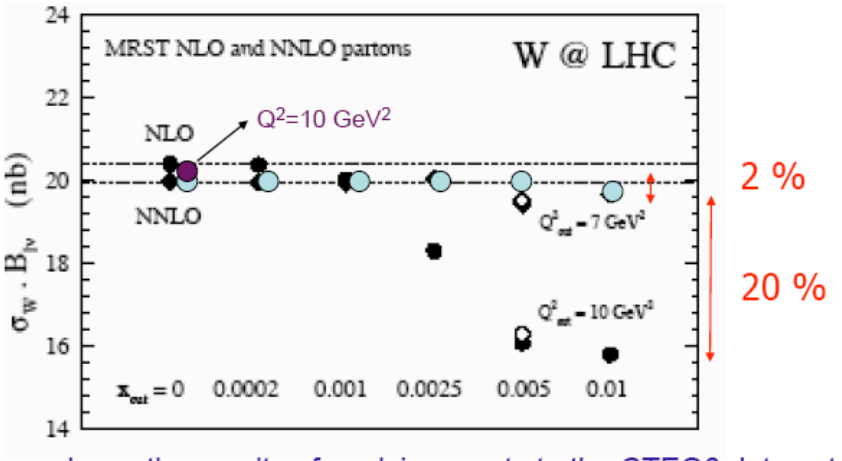
- Note that there have been a series of previous meetings organized by Steve Mrenna and myself dealing with these types of issues for Run 2
  - cepa.fnal.gov/patriot/mc4run2/index.html

Topics of investigation

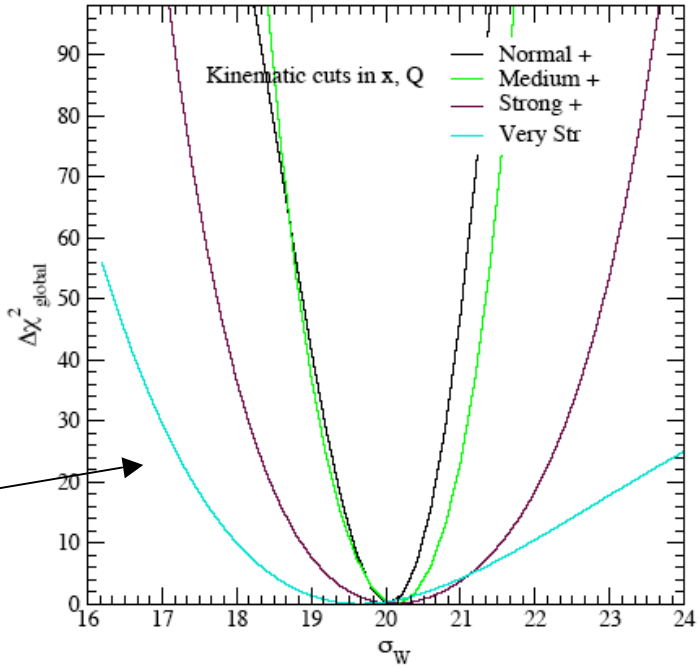
- PDF's and event classification
  - is NLO DGLAP evolution sufficient for describing Tevatron/HERA/LHC data? What is the impact of NNLO pdf's and cross sections
  - pdf uncertainties and efficient use in analyses/calculations
    - why aren't you using LHAPDF (if you're not)?
    - v3 of LHAPDF at durpdg.dur.ac.uk/lhapdf3/
  - impact of Tevatron data on global pdf fits
    - do stand-alone fits using only Tevatron (or LHC) data make sense?
  - jet algorithms, both cone and k_T
    - are theorists and experimentalists looking at the same thing?
    - are experimentalists really looking at what they think they're looking at?

NLO DGLAP

- Is there a *tension* between HERA and Tevatron data requiring NNLO DGLAP to resolve?
  - MRST study: hep-ph/0308087
- 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
  - see talk in Monday session
  - this curve corresponds to little HERA data in fit (Q^2>100 GeV^2)



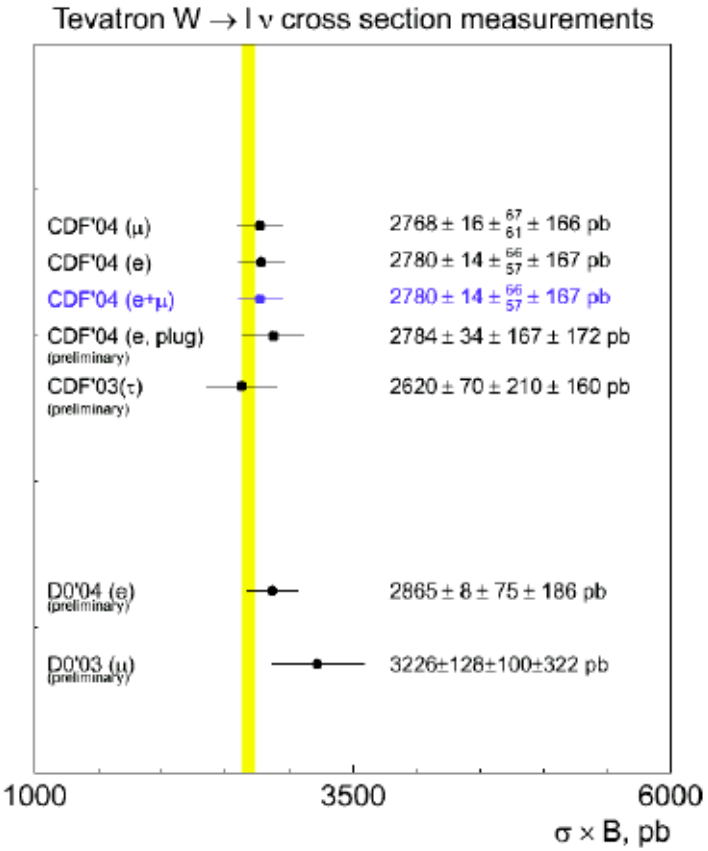
shows the results of applying x cuts to the CTEQ6 data set and performing a NLO fit.

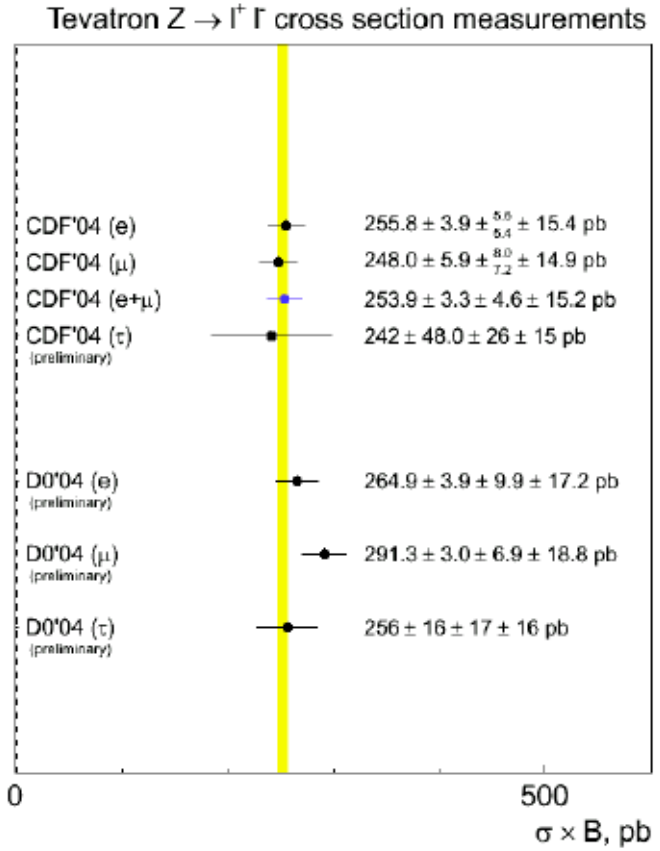


LM study of W cross section at the LHC using CTEQ6 dataset

W cross section at the Tevatron

Inclusive W/Z x-section measurements





- Overall good agreement with the NNLO calculations
- Experimental uncertainties (~6%) dominated by the luminosity

W cross section as luminosity monitor

$W \rightarrow l\,\nu$ 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

PDF uncertainties

- MRST uses $\Delta\chi^2$ of 50 for 90% CL; CTEQ uses $\Delta\chi^2$ of 100
  - each analysis contains over 2000 data points from a variety of processes
  - Santa Barbara accord: $\Delta\chi^2$=70?
- **In new version of LHAPDF, can keep all pdf's in memory at same time**
  - generate events using central pdf; store pdf*pdf weights for error pdf's
  - what sort of problems if this technique is used with parton shower Monte Carlos where initial state Sudakov factors depend on the slopes of the pdf's

top at the Tevatron; study in progress

J. Campbell, J. Huston; hep-ph/0405276

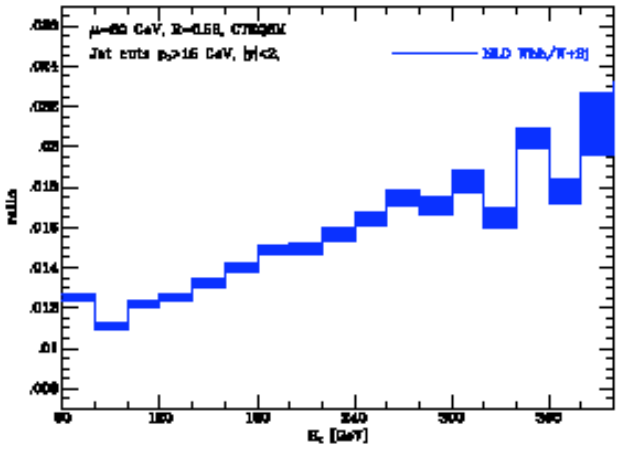
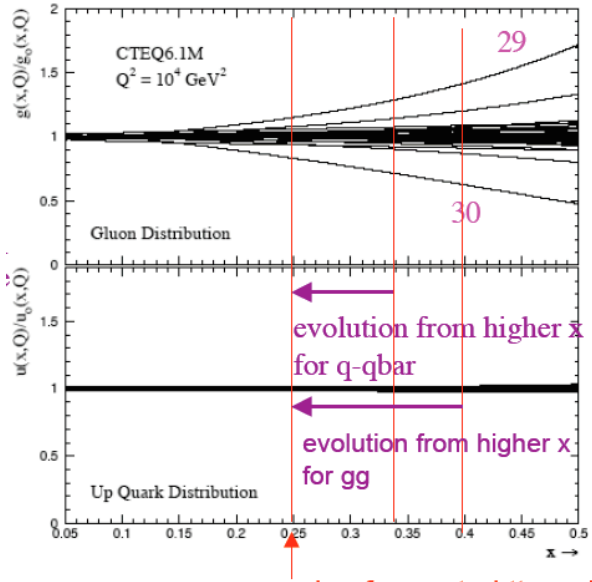


Figure 19: The PDF uncertainty for the ratio of $Wb\bar{b}$ and Wjj, plotted as a function of H_T, calculated using the CTEQ6 error PDF set.

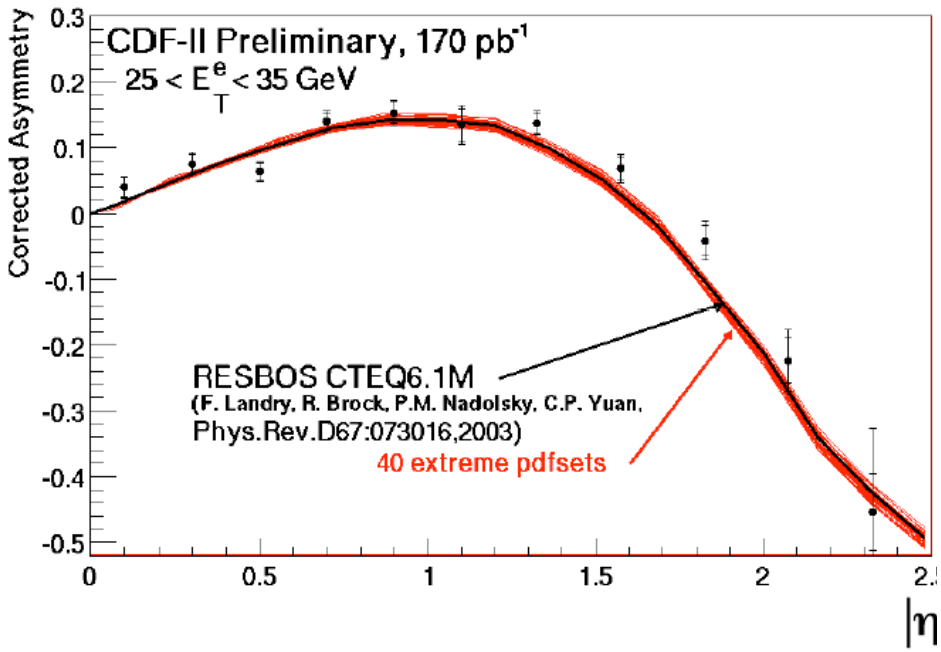


x value for central tt production

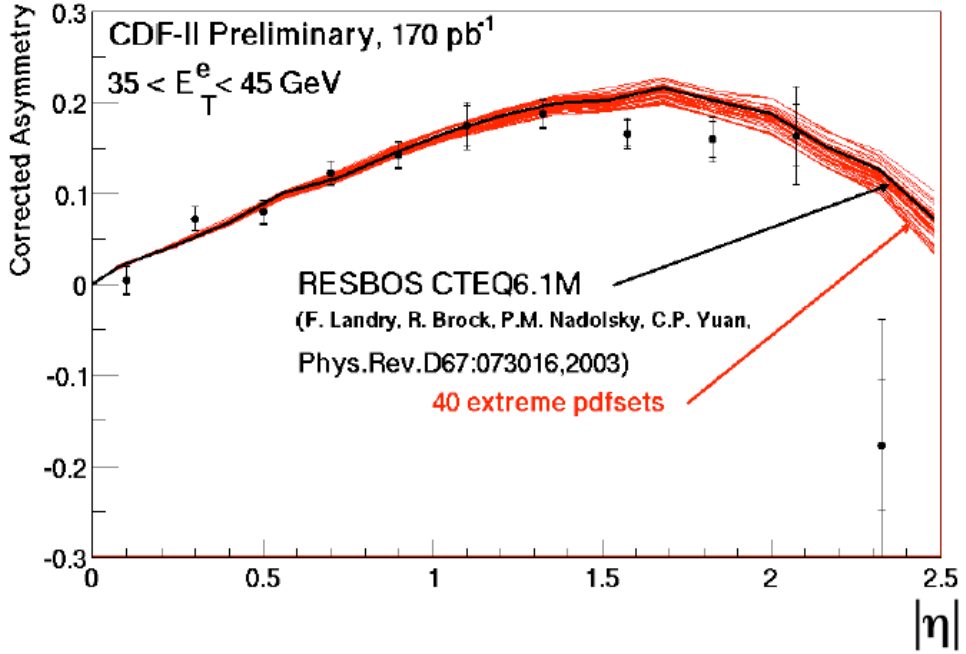
W asymmetry

error pdf's that have largest impact on W mass uncertainty also cause large deviations at high η

CTEQ6.1M with RESBOS at NLO

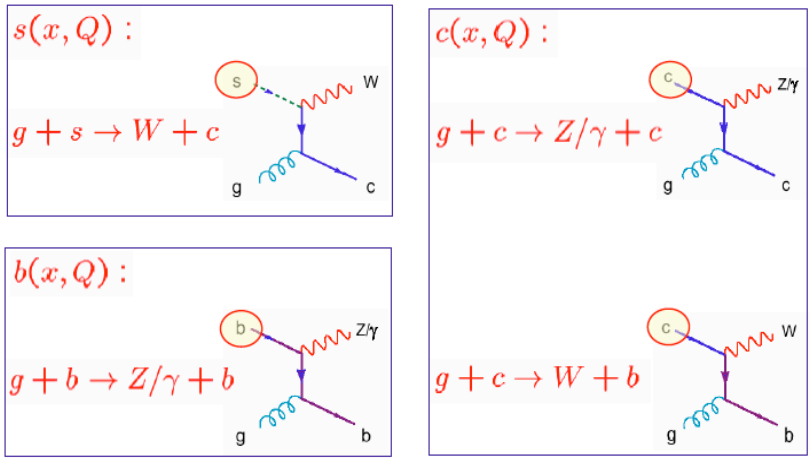


CTEQ6.1M with RESBOS at NLO



Heavy flavor pdf's

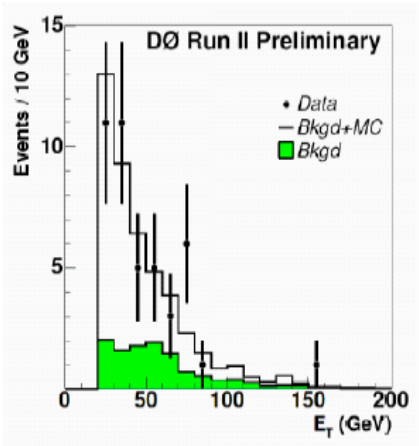
Probing the Sea Quark PDFs: s, c, b using tagged final states $W/Z/\gamma + c/b$?



The D0 measurement of Zb/Zj

$$\frac{\sigma(Z+b)}{\sigma(Z+j)} = 0.024 \pm 0.005(stat)\,^{+0.005}_{-0.004}(syst)$$

Theory NLO (F.Maltoni et al.): 0.018 +/- 0.004



Main sources of systematic uncertainty:

- b/c tagging efficiencies
- background estimation
- theory uncertainty on σ(Z+c)/σ(Z+b)

Proposal for the TEV4LHC

Study "inclusive" bottom measurements in W/Z production

Why ?

theory: we can predict cross sections extremely well
experiment: new approach, maybe better sensitivity

How ?

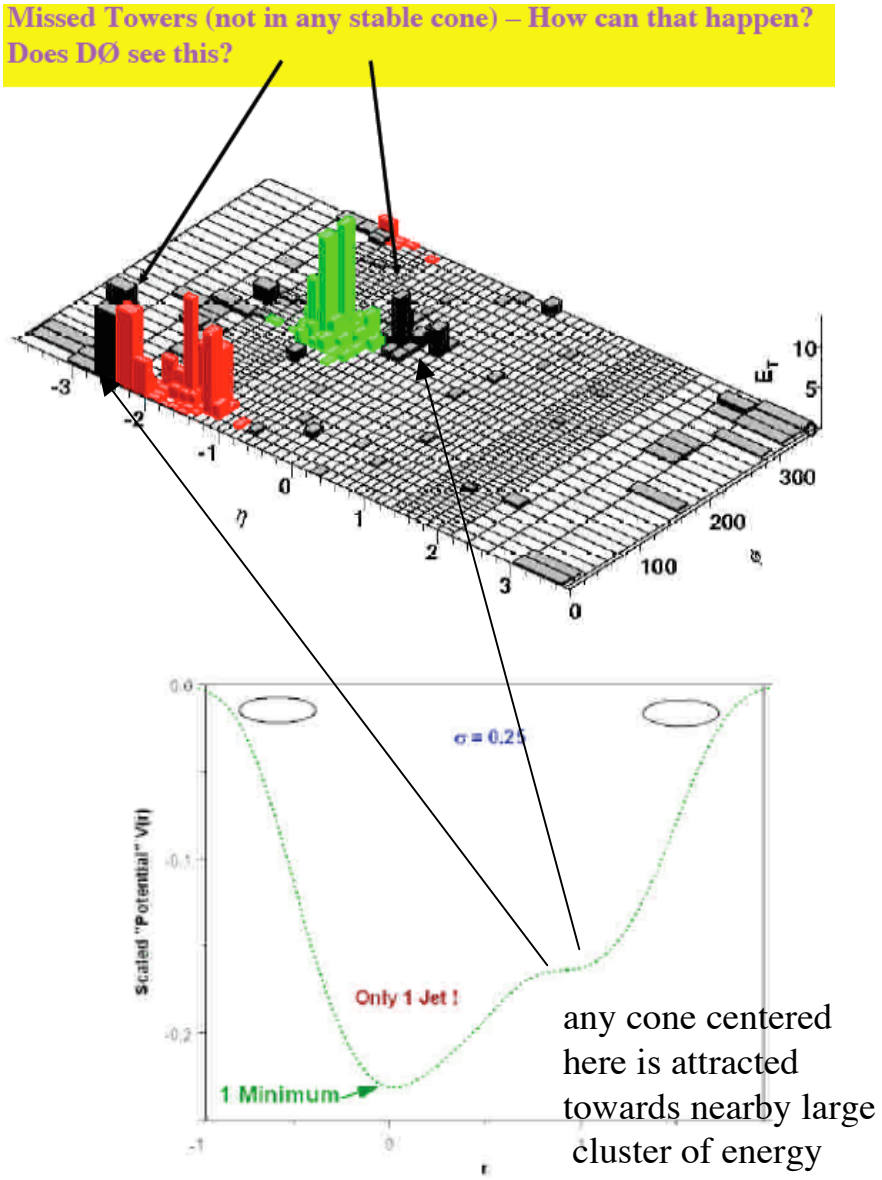
theory : perform the new NLO (and NNLO) calculations for Z and W that are needed

experiment: look at what CMS has done, use CDF and DO data for Wbb and Zbb to test feasibility, find efficiencies, etc...

Higgs Working Group @ TEV4LHC, September 2004

Jet algorithms

- 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*



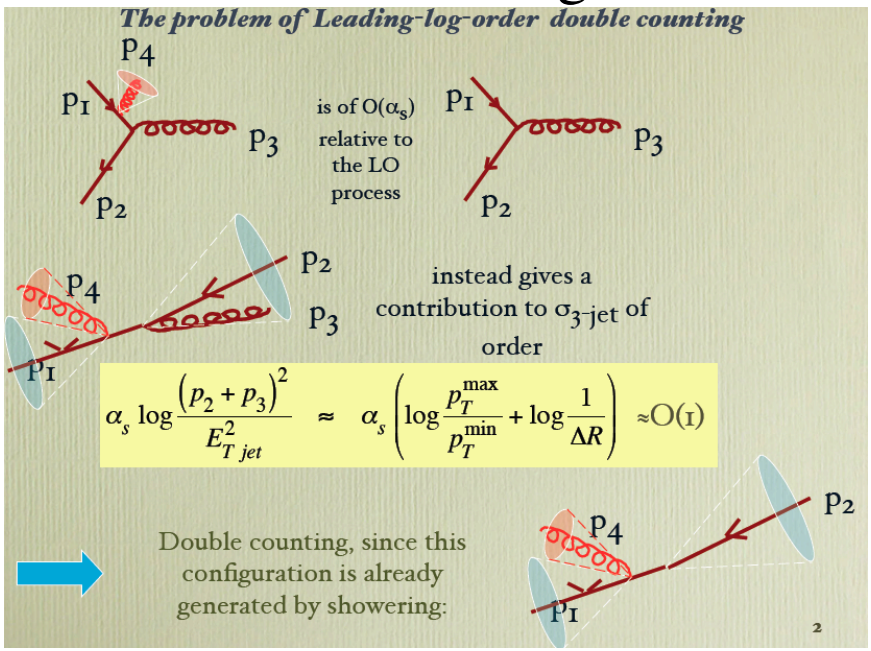
Topics of investigation

- Hard scattering and hadronization
  - testing of matrix element-parton showering matching
    - CKKW
    - MLM (L stand for Luigi by the way)
  - comparisons to NLO where available
    - *validation* of matching
  - pilot studies with MCatNLO
  - testing new parton shower approaches
  - 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
  - hadronization corrections
    - crucial for NLO comparisons, especially at low E_T

Matrix element-parton shower matching

- Les Houches accord for interface between matrix element and parton shower programs has become universal
- But need to control size of unwelcome logs

mlm: June 11 meeting of ME/MC



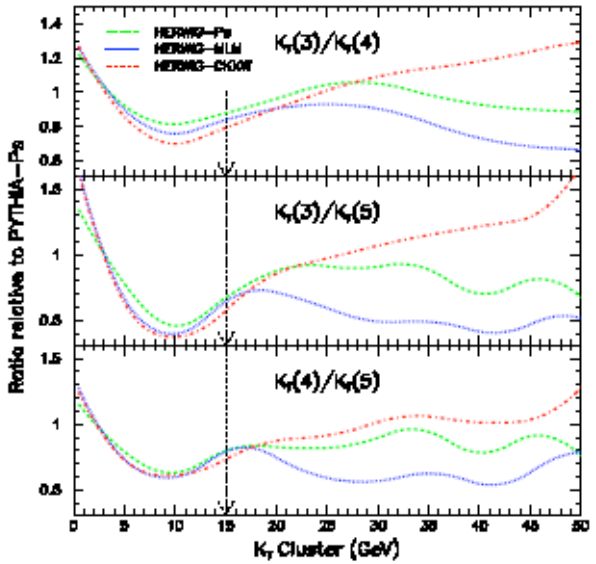


Figure 26: Similar to Fig. 19 but comparing the distributions from HERWIG and PY using the pseudo-shower procedure, HERWIG using the MLM procedure, and HERWIG using the CKKW procedure for a matching scale of 15 GeV.

- mlm and CKKW approaches for controlling logs both in use at Tevatron

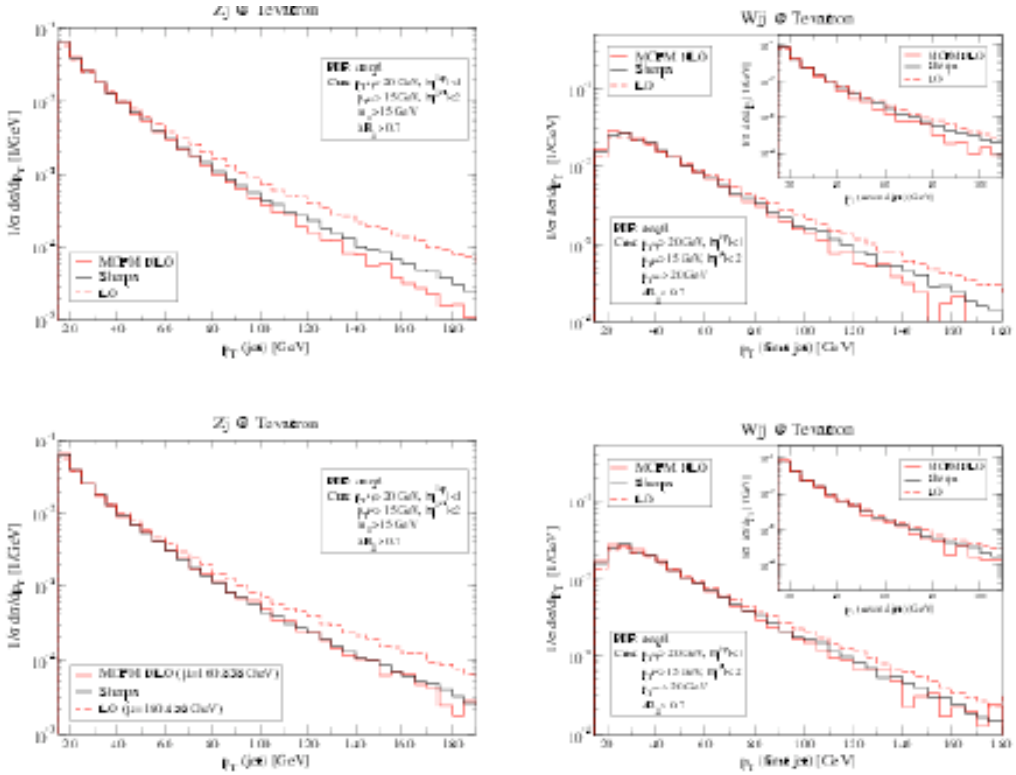
S. Mrenna and P. Richardson
hep-ph/0312274
systematic errors from comparison

W/Z + jets at the Tevatron

- Interesting physics and a great laboratory for testing theoretical tools
- **In the near future, we will produce absolute W/Z + n jet cross sections**

  corrected to both hadron and parton level in a wide variety of kinematic variables
- So that easy comparison to any LO/NLO calculation can be made

Frank Krauss: comparisons of Sherpa and MCFM



NLO vs LO behavior

Don't rely just on LO predictions

J. Campbell, J. Huston; hep-ph/0405276

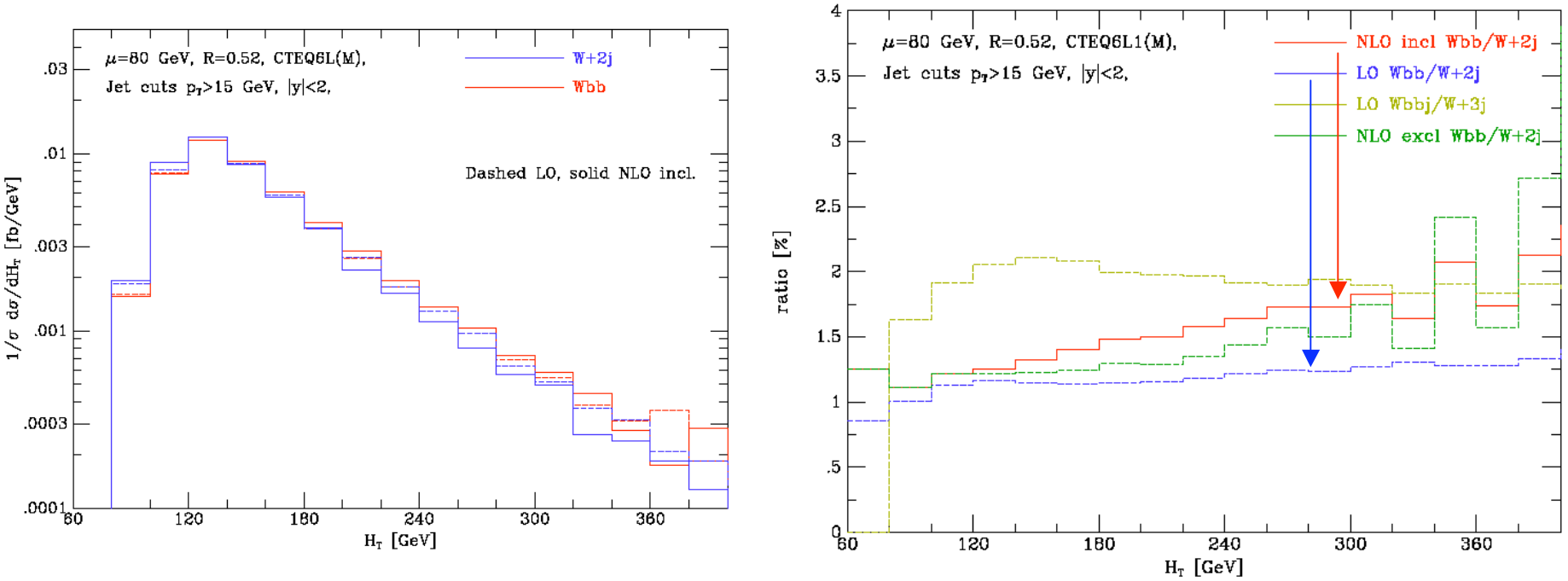


Figure 12: The H_T distributions for $Wb\bar{b}(j)$ and $Wjj(j)$, normalized to the same area.

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

Background studies for WW->H at LHC

- For W+>=2 jets at Tevatron
  - look at $|\eta_1-\eta_2|$ as a function of p_T^{jetmin}
  - Compare to MCFM LO/NLO, Herwig/Pythia/CKKW
- For W+>=3 jets
  - $\Delta\eta_3^*$ distribution as a function of p_T^{min} and $|\eta_1-\eta_2|$
  - 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
$\|\eta_1-\eta_2\|>2$	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 %

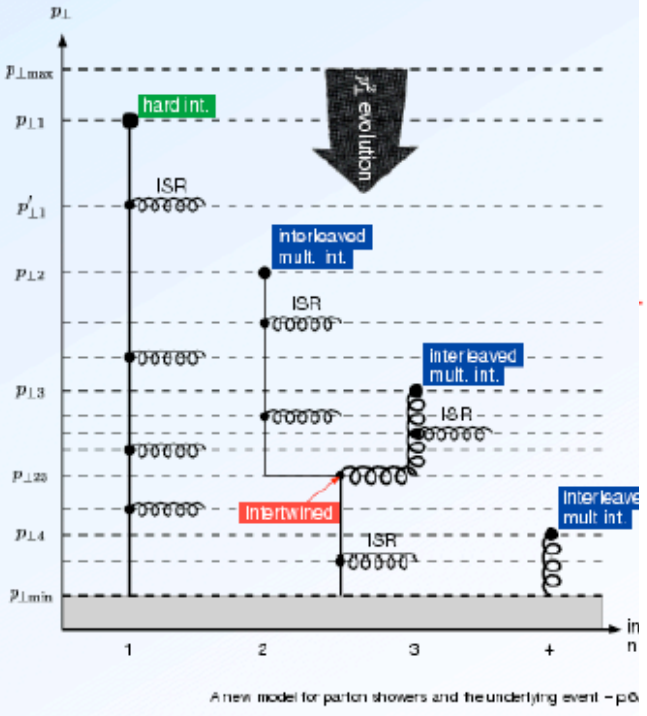
- No NLO calculation for W+3j available
  → substantial scale dependence
- 3 jet fraction is large
  → fixed order perturbation theory insufficient

More reliable predictions from parton shower programs?

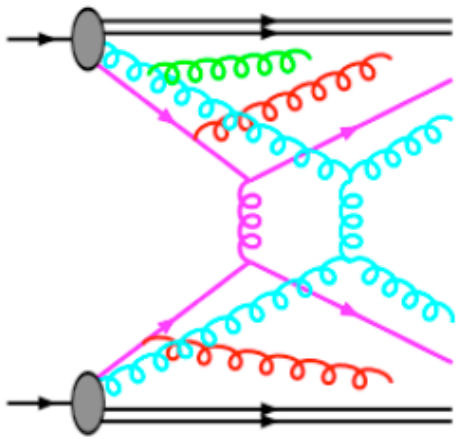
New parton showers

New k_T-ordered parton shower: Sjostrand and Skands: hep-ph/0408032

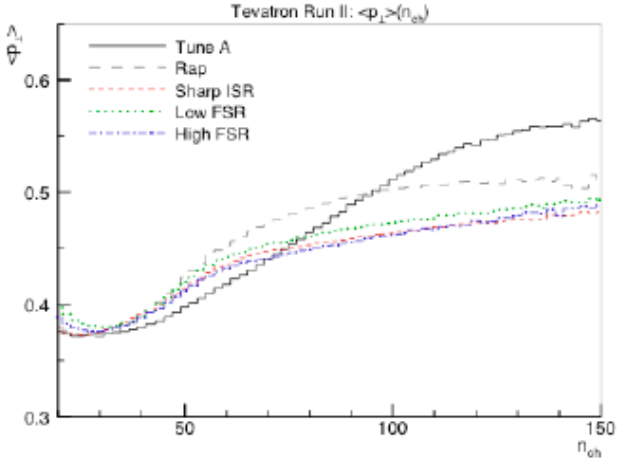
- This led us to develop a new sophisticated model for UE (and min–bias) → JHEP 0403 (2004) 053.
- But still each interaction was considered separately, with *its* set of ISR and FSR.
- That's probably not the way it happens in real life...
- The new picture: start at the most inclusive level, $2 \to 2$. Add exclusivity progressively by evolving *everything* downwards in *one* common sequence:
  → Interleaved evolution
- (→ also possible to have interactions *intertwined* by the ISR activity?)



A new model for parton showers and the underlying event – p6



. . $\langle p_\perp \rangle (n_{ch})$ problematical

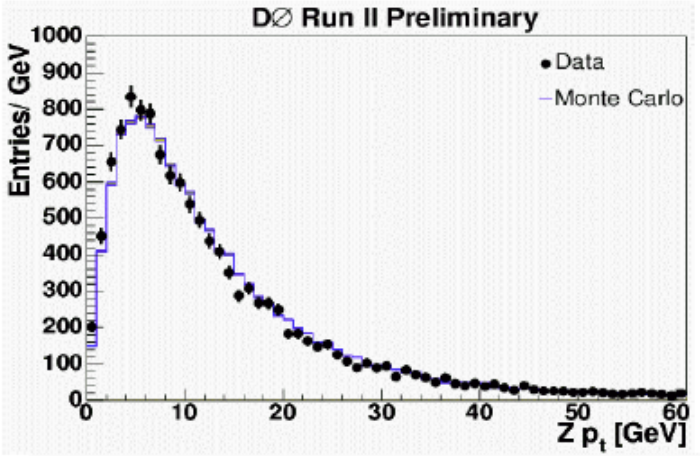


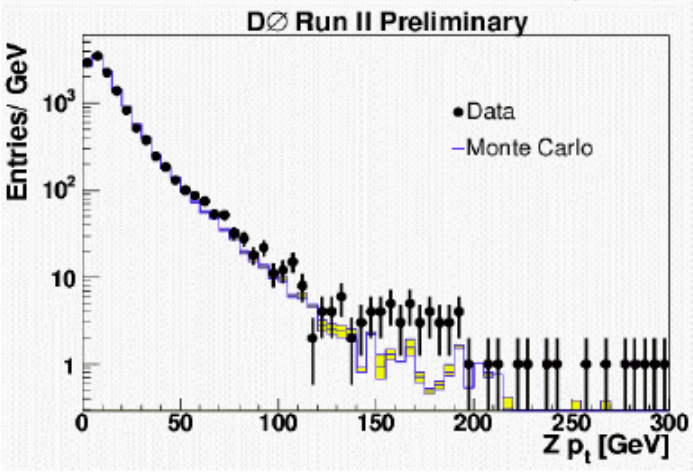
⇒ how are final-state colours correlated?

Soft gluon radiation

Run II differential W/Z cross sections

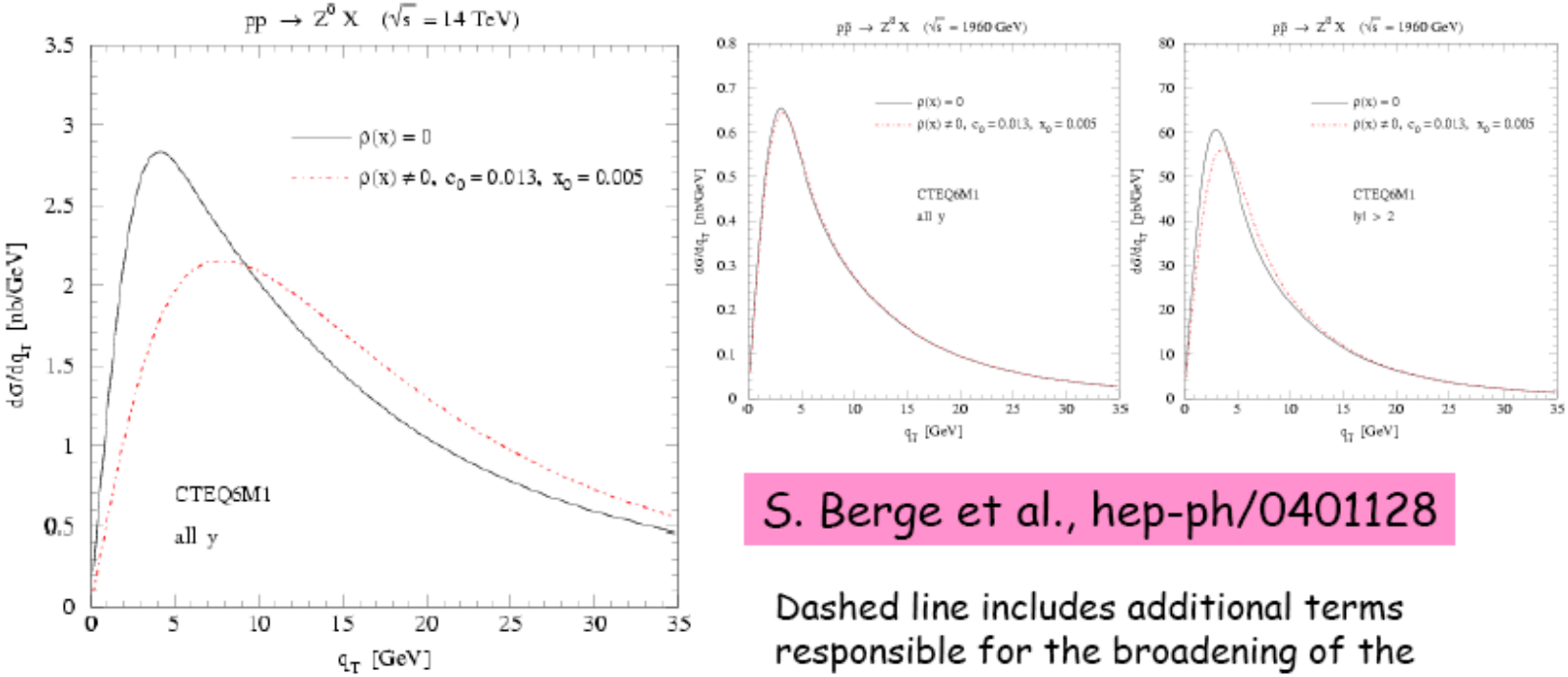
- $d\sigma(p\bar{p}\to W/Z)/d\,p_T$
- Low Pt end: one of the important inputs for W mass and width measurement
- Need good understanding of the resolution (exp)
- Need understanding of the soft gluon resummation (th)
- High-Pt end: any hints of new physics?
- Need good understanding of backgrounds





Soft gluon radiation

Rapidity dependence important at LHC



S. Berge et al., hep-ph/0401128

Dashed line includes additional terms responsible for the broadening of the distributions at low-x.

Can we learn something useful for the LHC by measuring d σ(ppbar->W/Z)/d pT dη?

Topics of investigation

Single Top searches

- DØ and CDF have set limits on the production of single top production

95% C.L. limits Observed (Expected)

Channel	CDF (pb)	D0 (pb)
s+t	<17.8 (13.6)	<23 (20)
t	<10.1 (11.2)	<25 (23)
s	<13.6 (12.1)	<19 (16)

Run II (~160 pb^{-1})

Analyses turns out to be harder (experimentally) than expected from phenomenological predictions
Something to keep in mind when making predictions about Higgs search at LHC.

Topics of investigation

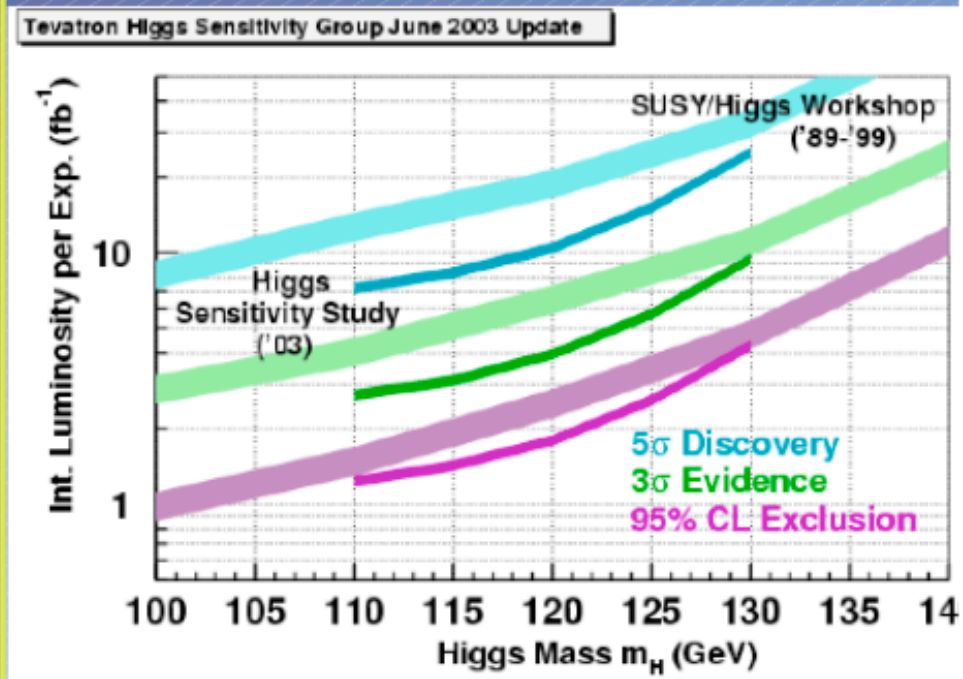
Single top observation

- Current analyses would need several fb^{-1} for observation
  - Particle ID, b-tagging not as efficient as predicted
  - Large systematic uncertainties from background modelling and detector understanding
  - Analyses methods need optimization to make and observation soon
- Work in progress
  - Ever improving particle ID and understanding of detector effects
  - Accurate models for signal and background benefits from recent NLO calculations
  - Working on multivariate analysis techniques (NN, Matrix Element, ...)
- Need to work with theorists to identify variables that give good signal-background separation – not just at parton level, but for experimental observables.

Higgs production

Combined Results

- Combined DØ/CDF result
  - Assumes luminosity from two experiments
- 10% dijet mass resolution
- Run IIB silicon
- Width of HSG bands determined by method uncertainty
  - No systematics included
- Width of SHWG bands given by analysis uncertainty
- SHWG included H→WW
  - contributes at high m_H



Low mass region 95% excl. or 3σ by 2008
This is difficult region at LHC

Diphotons

TeV4LHC

Open Questions

Apart from a brief presentation of CDF results, the biggest questions might be:

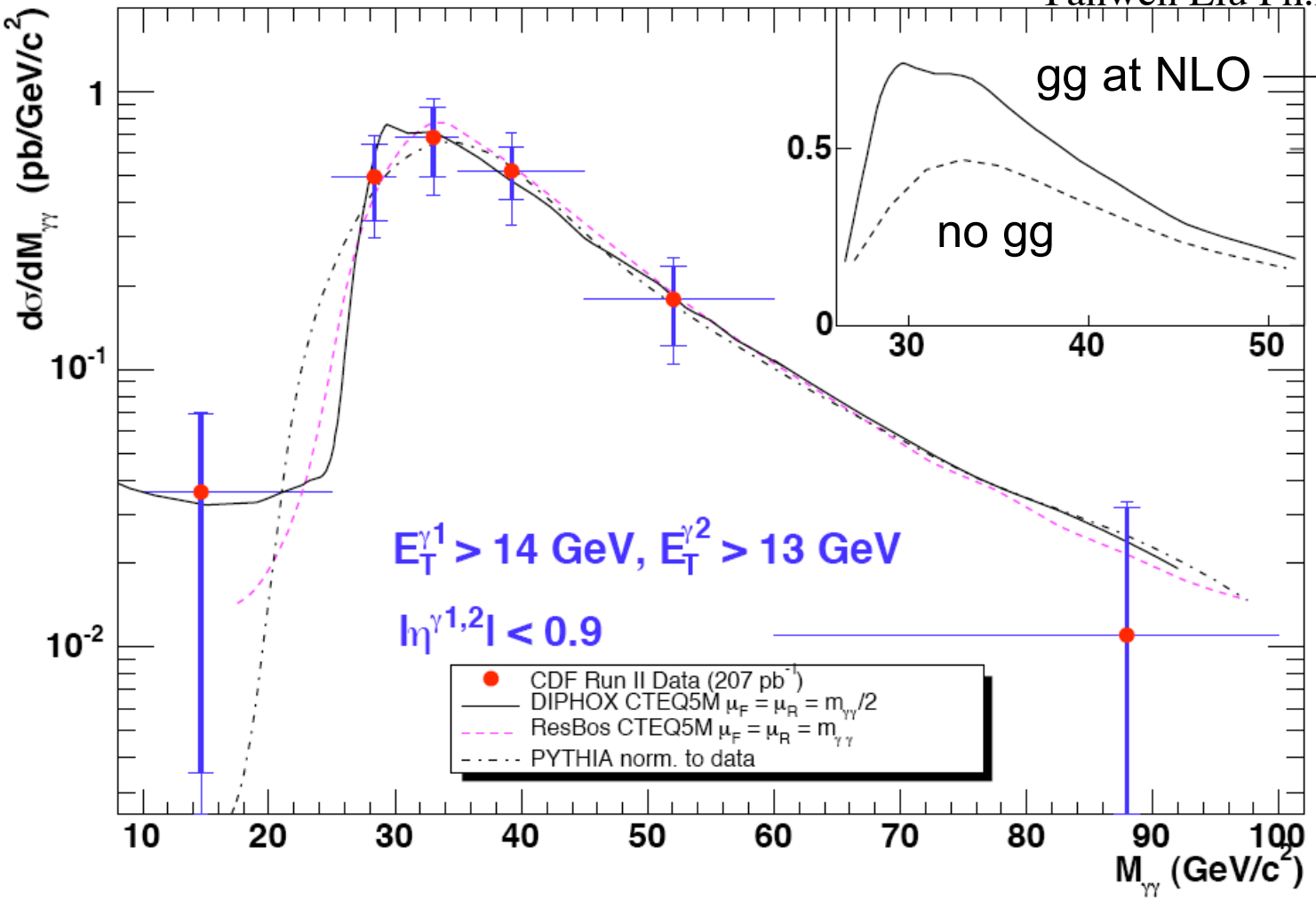
- Does LO/NLO get the SM diphoton x-sec and p_T right ?
- How accurately can we state that?
- Is that the only significant background to the Higgs search or will dijets be a big problem?
- The latter probably can't answered by us easily, but if we look into the existing LHC work, we could probably comment on it.

  e.g.) If the fake rate seems reasonable, or

  Does CDF Monte Carlo predict the right fake rate?

Diphotons in Run 2

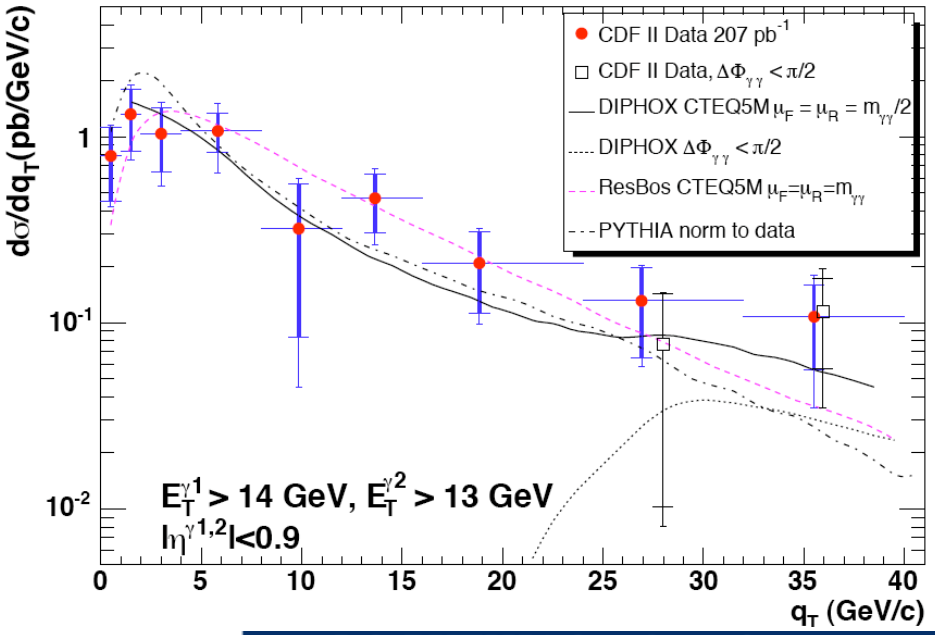
Yanwen Liu Ph.D 2004

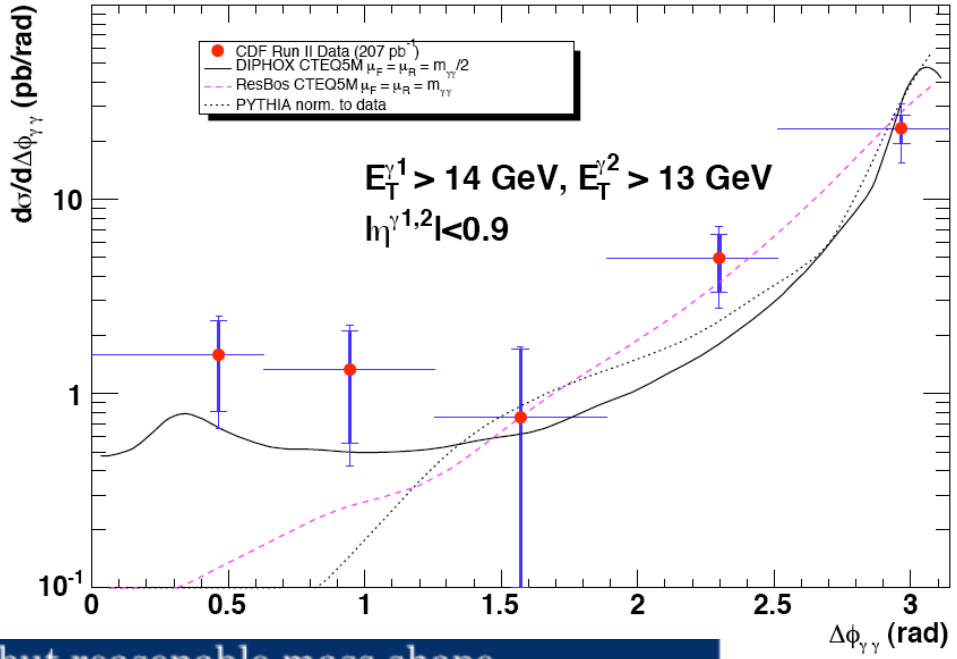


→ K-factor for gg is large (100%)

Other diphoton variables

small q_T, large $\Delta\phi$: effects of gluon resummation evident
large q_T, small $\Delta\phi$: NLO fragmentation important





- LO PYTHIA low by a factor ~2.0, but reasonable mass shape
- DIPHOX breaks down at low qt due to singularities in NLO
- RESBOS does better at low qt due to continuous ISR resumming
- DIPHOX shows additional source at low m($\gamma\gamma$), small $\Delta\phi$, and qt>30 GeV. These are ($qg \rightarrow gq\gamma \rightarrow g\gamma\gamma$) where the q fragmented to a photon

Sungwon Lee *TeV4LHC Workshop @ Fermilab* *27*

We need a full NLO resummed calculation.

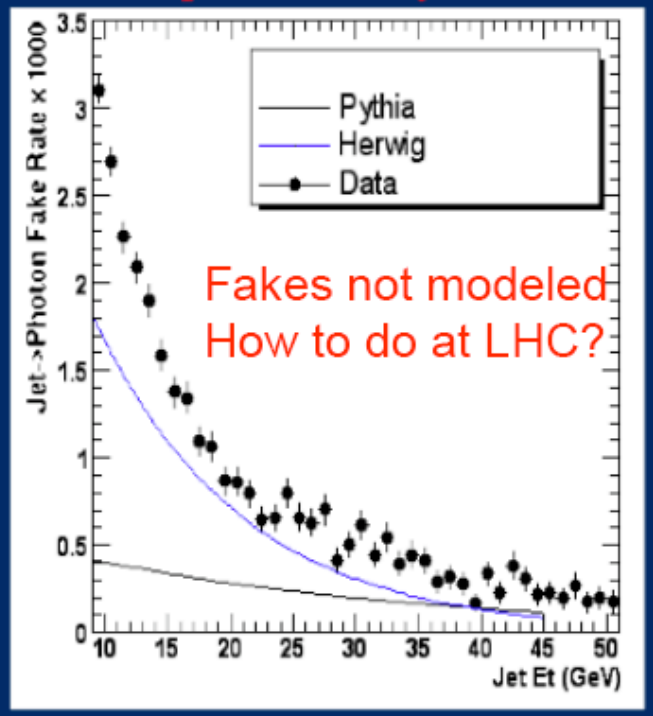
Diphoton backgrounds

Photon Fake Rate from Data

A. Nikitenko (Plenary Talk)

- Rate of jets with leading meson (π^0,η) which cannot be distinguished from prompt photons: Depends on
  - detector capabilities, e.g. granularity ofcalorimeter
  - cuts!
- Systematic error about 30-80% depending on Et
- Data higher than PYTHIA and HERWIG
- PYTHIA describes data better than HERWIG

CDF (preliminary result)



At TeV Jet→γ miss ID is obtained from γ+jet data.
We should evaluate how does it work with LHC detectors

Physics Landscapes

Proposed Topics

- The $\not{E}_T$ spectrum and *e.g.* evidence for extra dimensions.
  - inject more realism into this experimental study (and the others, too)
  - adopt Tevatron techniques for controling *fake* $\not{E}_T$
  - evaluate impact of jet energy scale, PDF uncertainties, instrumental backgrounds, and the underlying event
- Investigate light $\tilde{t}_1$ and $\tilde{b}_1$ signals at the LHC
  - is discovery feasible?
  - what triggers are needed? (recall small ΔM case)
  - study b and c-tagging – *especially for very high energy jets*
- What is the Z' and W' reach at the LHC, for *realistic simulations*?
  - scrutinize lepton-ID, especially at high energies (calorimetry, tracking ...)
  - impact of underlying event on isolation
  - note W' search involves large $\not{E}_T$
  - what can be done with di-jets (already quite 'interesting' at Tevatron)
  - verify previous background calculations

Physics Landscapes

- advanced reconstruction of electrons which Brems
  - identify and handle asymmetric calorimeter clusters
  - this is mainly a 'tools' study with wide ranging applications
  - DØ can investigate this directly with data
- lepto-quark and techni-color signals
  - current simulations are not very realistic
  - impact of underlying event on lepton isolation, and jet reconstruction?
  - existing techniques are based on tevatron analyses and probably are not optimal for the LHC
  - work can proceed in parallel with the Tevatron analyses

- Extend model-independent approaches like the one proposed by *Carena, Daleo, Dobrescu & Tait*
  - render Tevatron results in this formalism
  - What happens if you hypothesize an extra $SU(2)$, ie., W''s ?
  - make contact with the experimental studies for Z' (above)

- Identify cases in which Tevatron data is essential
  - as input to theoretical calculations (models).
  - to interpret signals seen at both Tevatron and LHC

- Gordy Kane proposes looking at 'patterns' of data to select-out the best candidates models.
  - can we come up with test cases (in the spirit of the benchmark points and slopes)?
  - what kinds of 'inclusive' measurements make sense?

Websites and future meetings

- TeV4LHC: conferences.fnal.gov/tev4lhc/
- QCD
  - www.pa.msu.edu/~huston/tev4lhc/wg.htm
  - see also www.pa.msu.edu/~huston/tevqcdwg/wg.htm
- 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 Brookhaven Feb 3-5, 2005
- Follow-up meeting at CERN in late April, 2005
- Final meeting at Fermilab in the fall of 2005
- Many of the issues are in common with the HERALHC workshop,cf
- **09/17/2004· Hera4LHC: Introduction, pdfs and diffraction***Albert de Roeck* 35 min ppt
- **Hera4LHC: Heavy quarks, jets and event generators***Michael Seymour* 35 min pdf

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

note catchy new logo seen for the first time at CERN here