W + jet production at CDF

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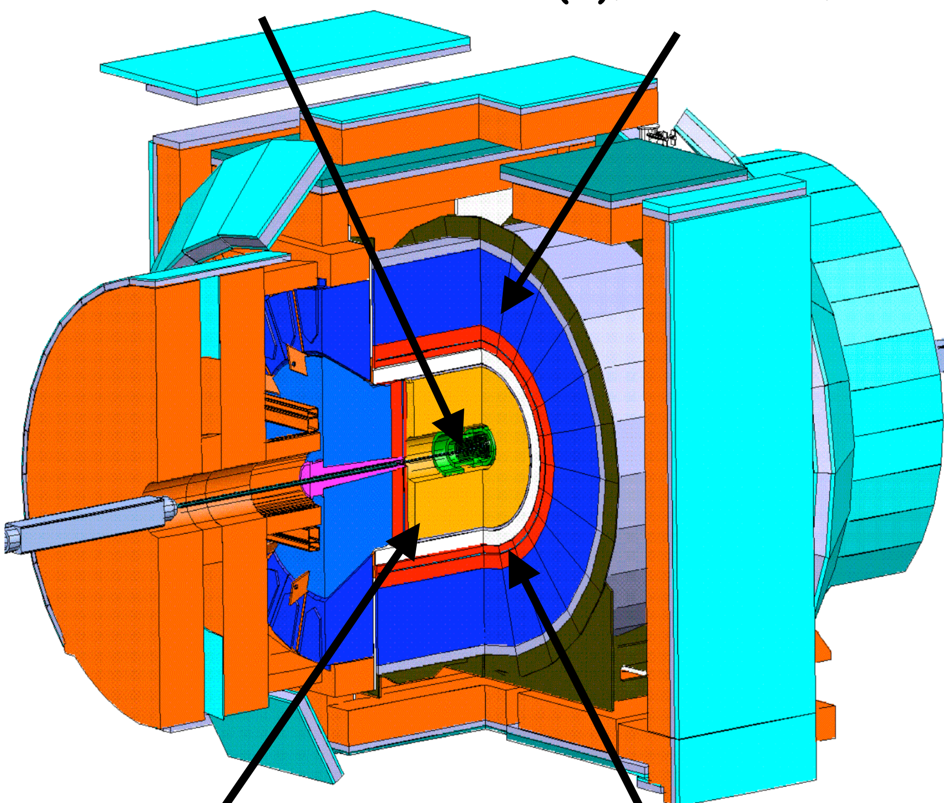
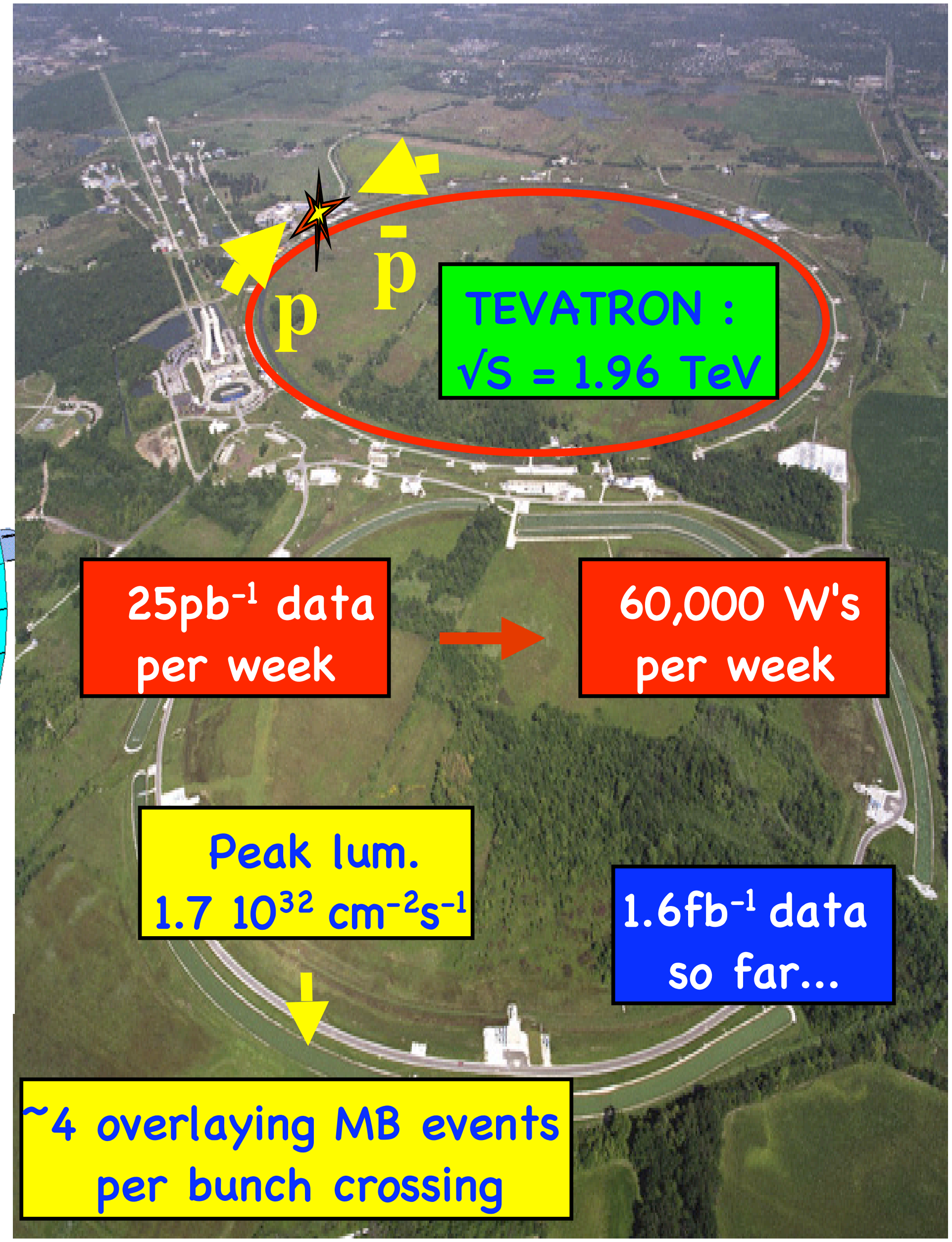
OUTLINE

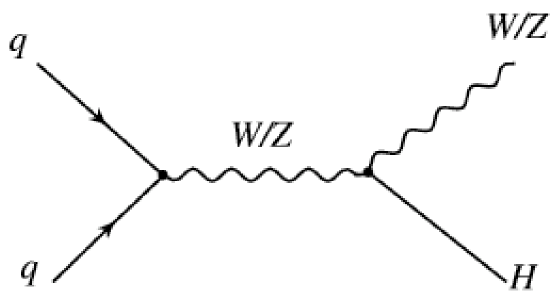
- Motivations for Study
- Monte Carlo Issues
- Measurement definition
- Background estimation
- Results
- Systematics
- Conclusions & plans

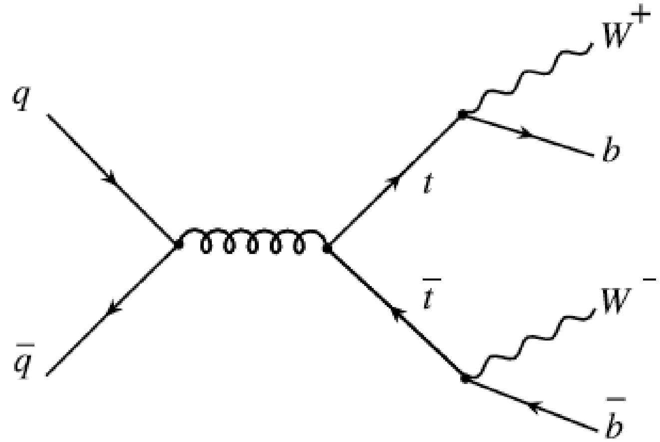
CDF and the Tevatron

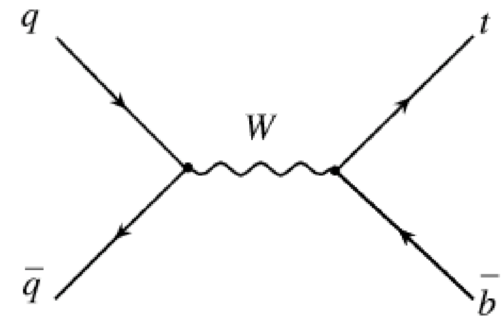




Motivation: Understanding a vital background







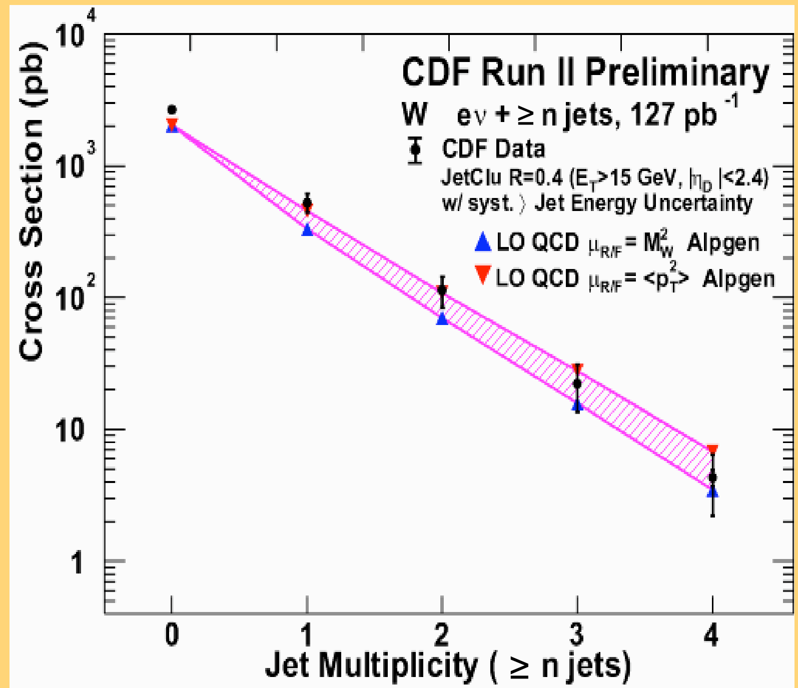
- Boson + jet is the final state for a number of important high p_T physics processes:
  - Top pair & single top production.
  - Higgs boson searches.
  - Searches for super-symmetric particles.
- All these signals are overwhelmed by large QCD production of boson + jets.
- It is crucial to have a good understanding of the boson + jets process.

Motivation: Test of pQCD Predictions

- Testing ground for pQCD in multijet environment
- The presence of a W/Z boson:
  - Ensures high Q^2 - pQCD
  - Large BR into leptons - easy to detect experimentally
- Key sample to test LO and NLO pQCD calculations
  - Pythia, Herwig: parton shower & hadronization, limited ME
  - AlpGen : W + n parton ME, interface to Pythia/Herwig for PS, MLM ME-PS matching scheme
  - Sherpa : W + n parton ME, APACIC showering, CKKW ME-PS matching scheme
  - MCFM: NLO ME W + 1 or 2 partons
  - MC@NLO: W+X (NLO ME + herwig shower)
- Study the underlying event in an alternative topology than inclusive multijets.

W + n Jets LO Predictions

- W + n parton LO ME calculation + parton shower + hadronisation:
  - W + ≥ n jets Cross-section
  - Jet kinematics for ≥ n jets
- Issues:
  - Dependence on Q^2 scale
  - Dependence on parton cuts
  - Phase space overlap when combine n parton samples
- Advances:
  - ME-PS matching - CKKW and MLM prescriptions.
  - NLO predictions.



LO W + ≥ n parton cross-section vs data: good within large Q^2 uncertainties.

Definition of our measurement

- Aim for a definition as much as possible independent of theoretical predictions and detector effects.

$$\frac{d\hat{\sigma}_{W \to e\nu}}{d(jet)}$$

- Restrict W decay to analysis acceptance.
- $P_T^{ele} > 20$ GeV, $P_T^{\nu} > 30$ GeV
- $WM_T > 30$ GeV/c^2, $|\eta^{ele}| < 1.1$
- Reduces theoretical dependence of measurement, without comprising usefulness.

- Jets: JETCLU cone 0.4, $E_T > 15$ GeV, $|\eta| < 2.0$.
- Jet energies corrected to hadron level and for multiple interactions - underlying event remains.
- Differential w.r.t. 1st, 2nd, 3rd and 4th jet E_T, 1st-2nd jet invariant mass and ΔR.

- This is not an EWK measurement - W is a clean signal for high Q^2 events within which we can examine jet kinematics.

Making the Measurement

Identify $W \rightarrow e\nu$ candidate events from high E_T electron and large missing E_T.

Reconstruct jets.

In each bin of the jet kinematic variable calculate:

$$\sigma = \frac{N^{cand} - N^{bkgd}}{A \bullet \varepsilon_{ID} \bullet L}$$

Backgrounds:

- QCD multijet
- Top pair
- $Z \rightarrow ee$, $W \rightarrow \tau\nu$
- WW
- Multiple interactons

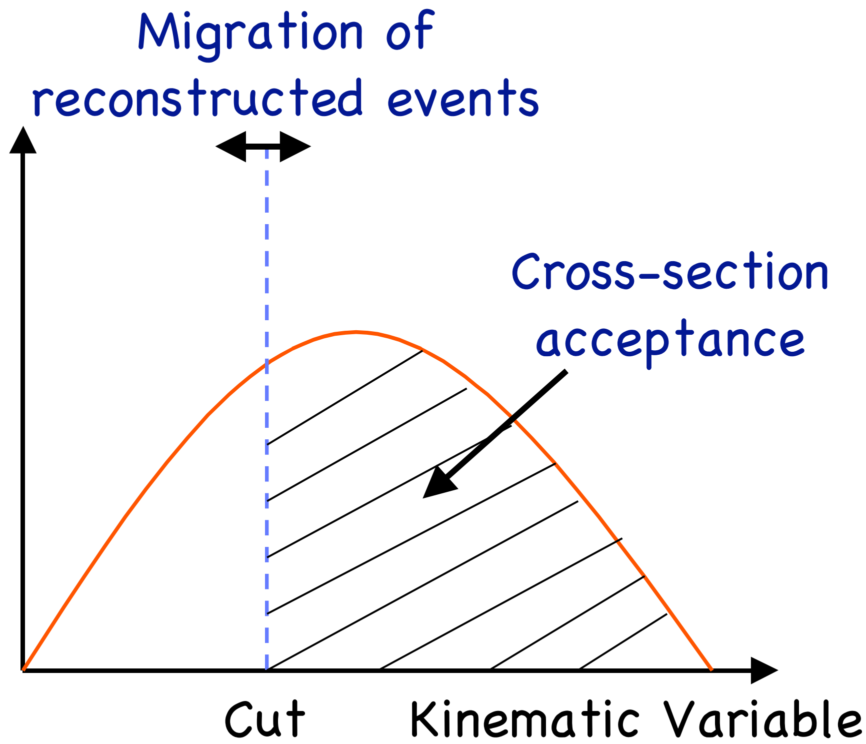
Dataset luminosity $320 \pm 20 pb^{-1}$

Acceptance and efficiency both estimated using detector simulated LO W + Jets Monte Carlo.

- Theoretical dependence enters the measurement via background and acceptance estimation – covered by systematics.
- Detector dependence removed by jet energy scale corrections and acceptance.

Acceptance and Efficiency

- W Cross-section phase space same as analysis acceptance.
- Acceptance factor reduced to accounting for detector resolution and local shape around cut.
- Reduces theoretical dependence of measurement.



- Use W MC for acceptance and electron ID efficiency:
  - Systematic on ID efficiency by comparing MC and Z data
  - Estimation of acceptance systematic by comparing different MC models

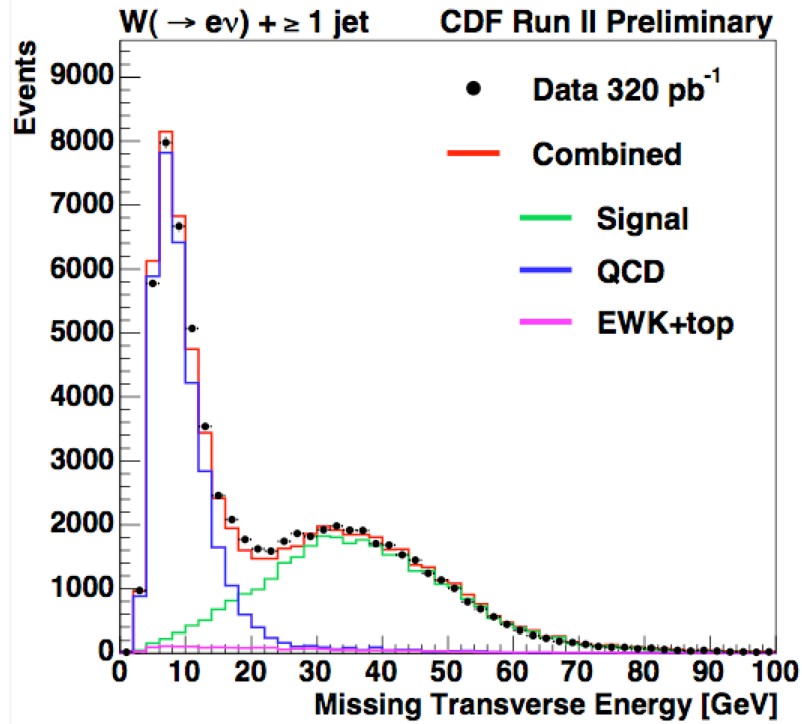
  } 5%

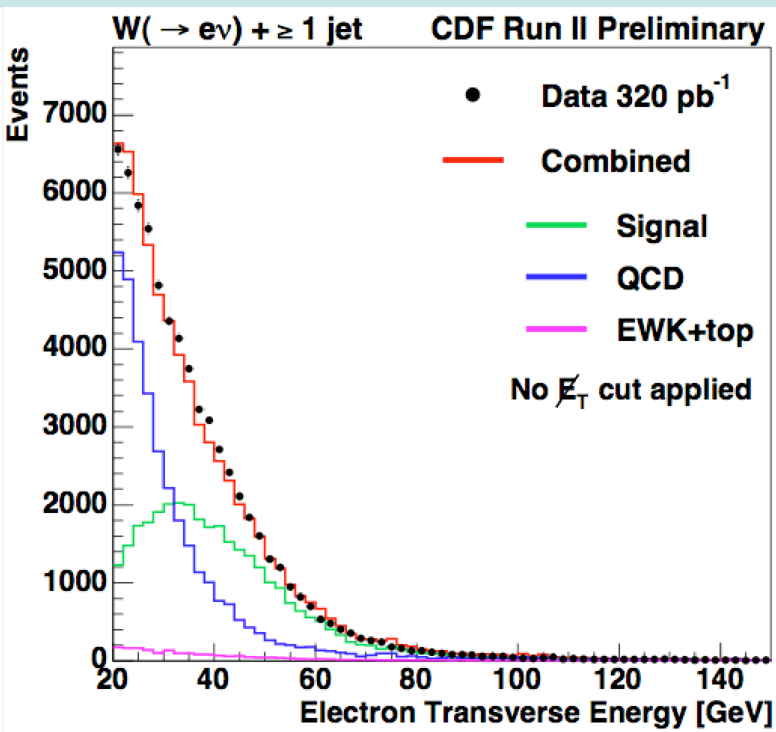
$$A \bullet \varepsilon_{ID} \approx 0.6 \pm 0.03$$

Largely independent of jet kinematics

Background Estimation

- QCD modelled by fake-electron sample formed from dataset.
- MC for other bkgds and signal
- Background normalisation from fit to data missing E_T distribution.
- Excellent agreement in other kinematic variables.

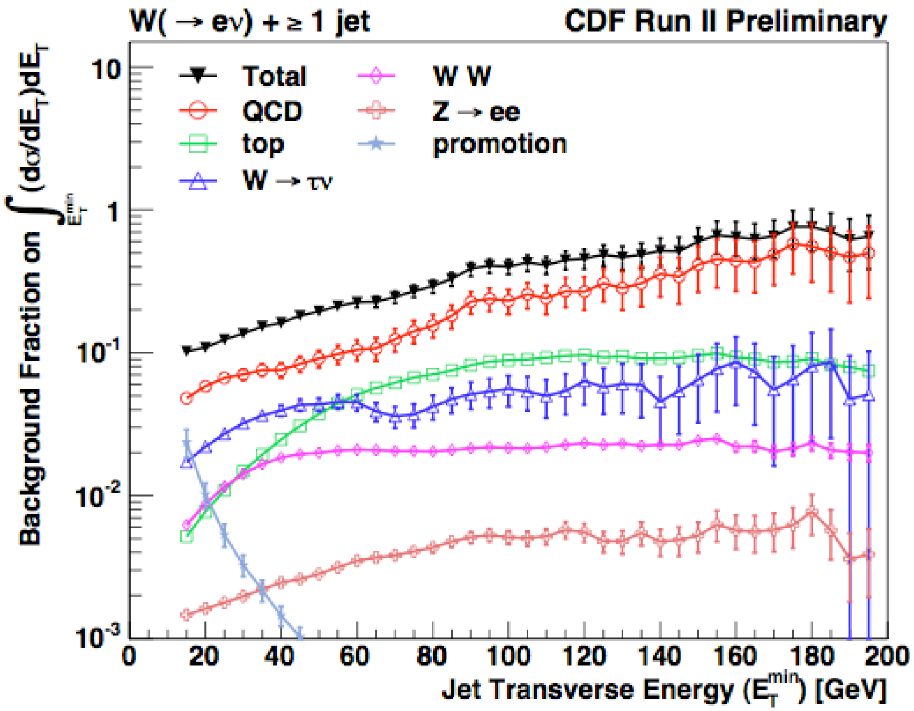


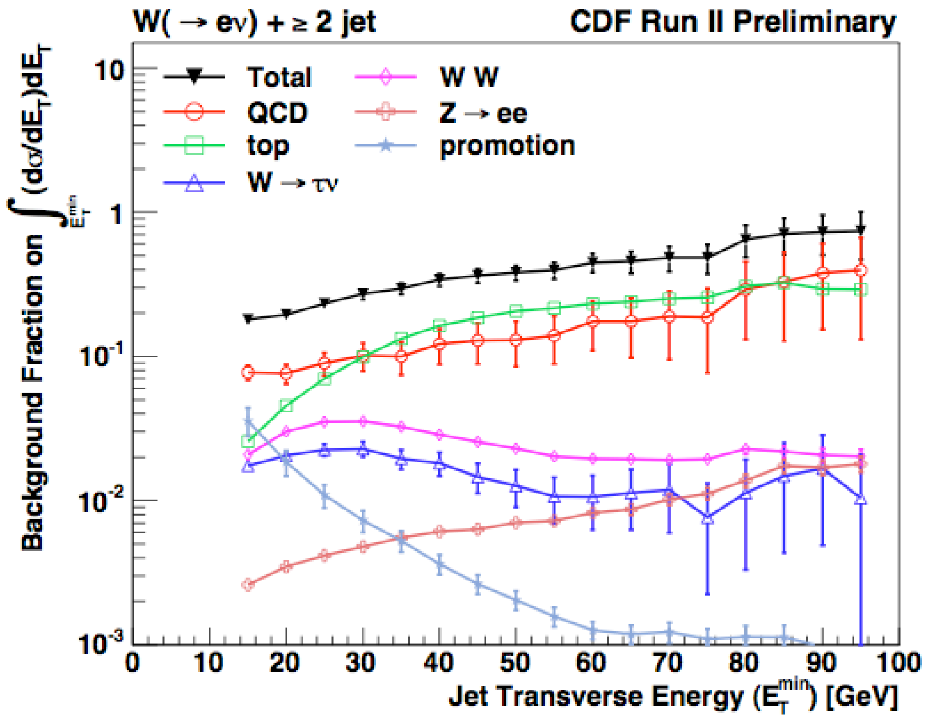


Background Systematics:

- Fake-electron statistics (dominant)
- Fake-electron QCD model (5-20%)
- Top cross-section (10-20%)
- MC model dependence (5%)

Background Fractions





- QCD is a substantial background contribution, dominating at low E_T.
- But in high E_T region Top pair production is dominant.

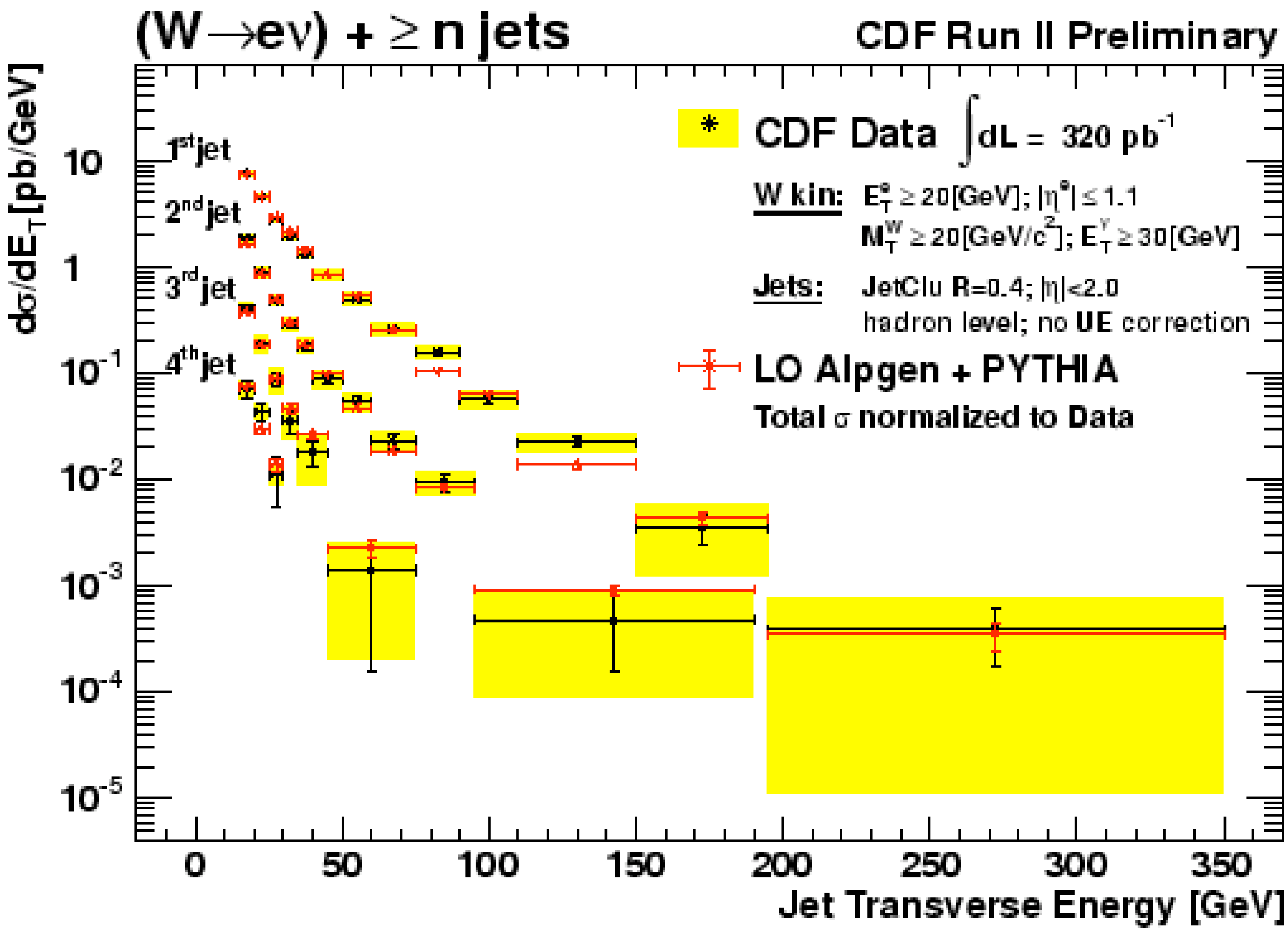
Promotion Background (small contribution at low E_T):

- Extra interactions can produce additional jet not associated to the W hard scatter.
- Estimate extra jet rate in minimum bias events, correct data on average as a function of the number of vertices.

CDF W+jets Differential Cross-Section

$$\frac{d\hat{\sigma}_{W\to e\nu}}{dE_T}$$

For 1st, 2nd, 3rd and 4th Jet E_T



MC has been normalized to inclusive data cross section in each jet sample!

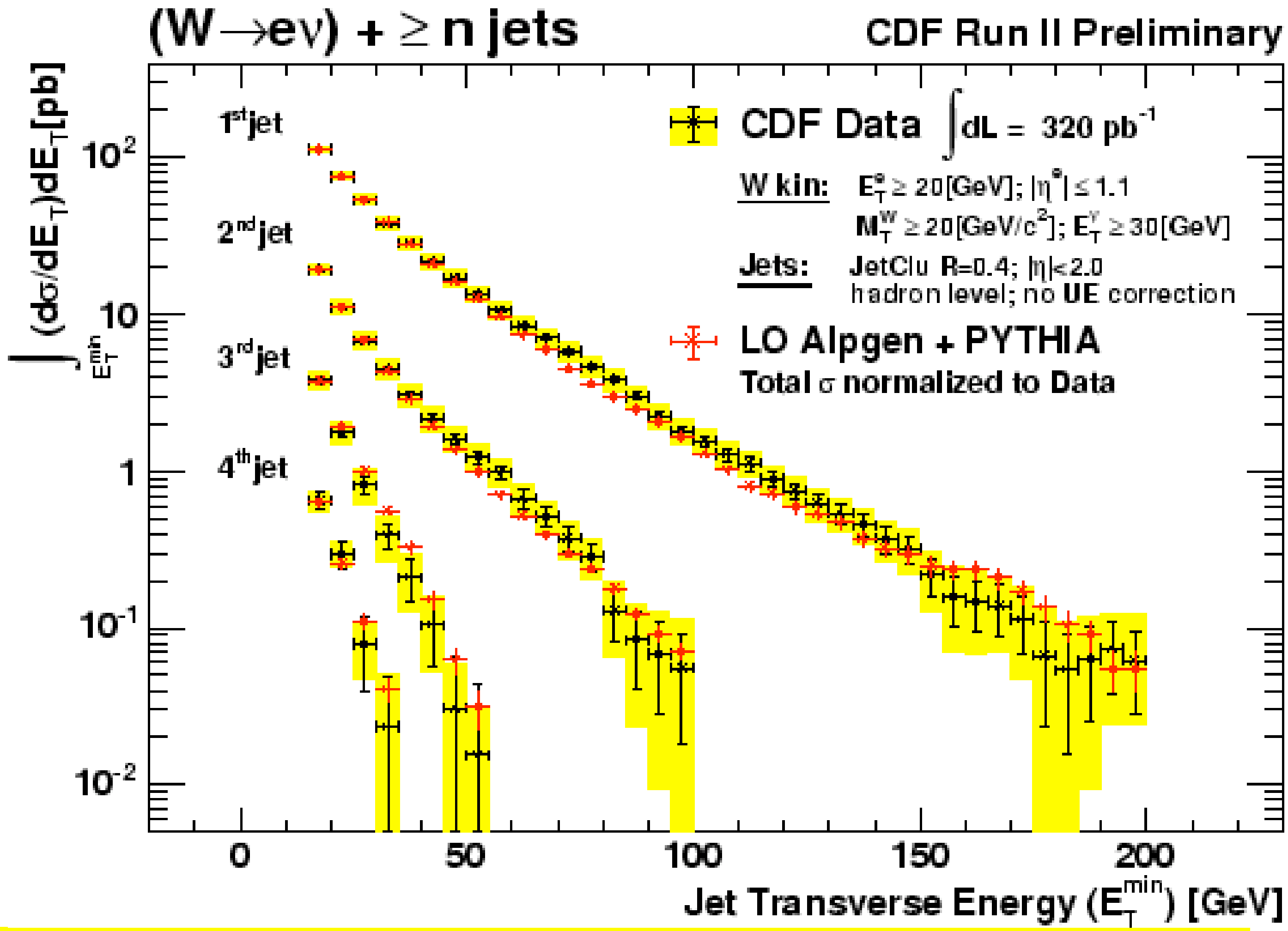
LO W + n parton prediction reproduces shape of $d\sigma/dE_T$ reasonably well.

CDF W+jets Integrated Cross-Section

$$\int_{E_T^{min}} \frac{d\hat{\sigma}_{W\to e\nu}}{dE_T} dE_T$$

For 1st, 2nd, 3rd and 4th Jet E_T

Essentially a measurement of $\sigma(W + \geq n \text{ jets})$ for different jet E_T thresholds.



MC has been normalized to inclusive data cross section in each jet sample!

First bin MC & data is in perfect agreement by construction.

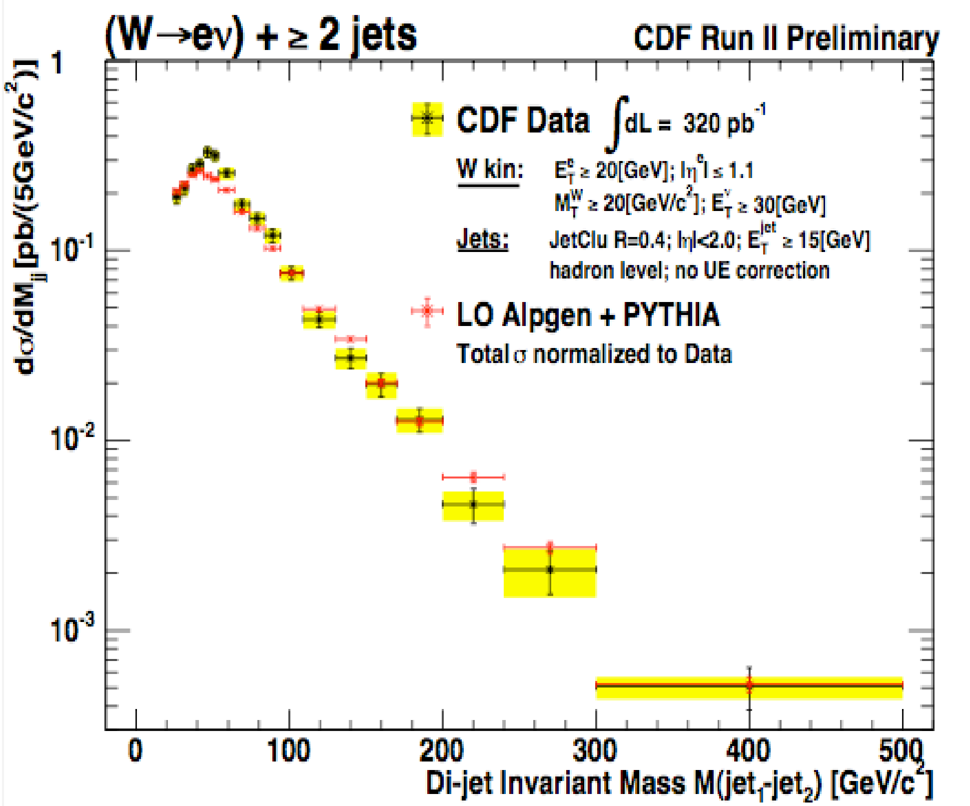
CDF W+jets Differential Cross-Section

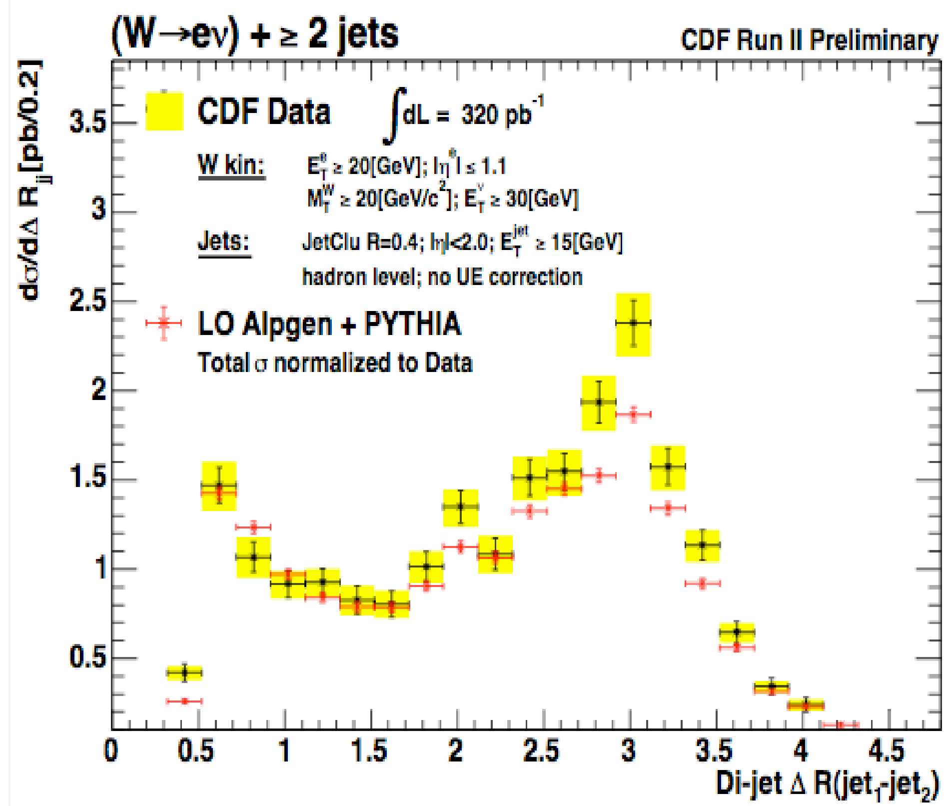
$$\frac{d\hat{\sigma}_{W\rightarrow e\nu}}{dM_{jj}}$$

Differential σ w.r.t 1st-2nd jet invariant mass in the W + ≥ 2 jet sample

$$\frac{d\hat{\sigma}_{W\rightarrow e\nu}}{d\Delta R_{jj}}$$

Differential σ w.r.t 1st-2nd jet ΔR in the W + ≥ 2 jet sample



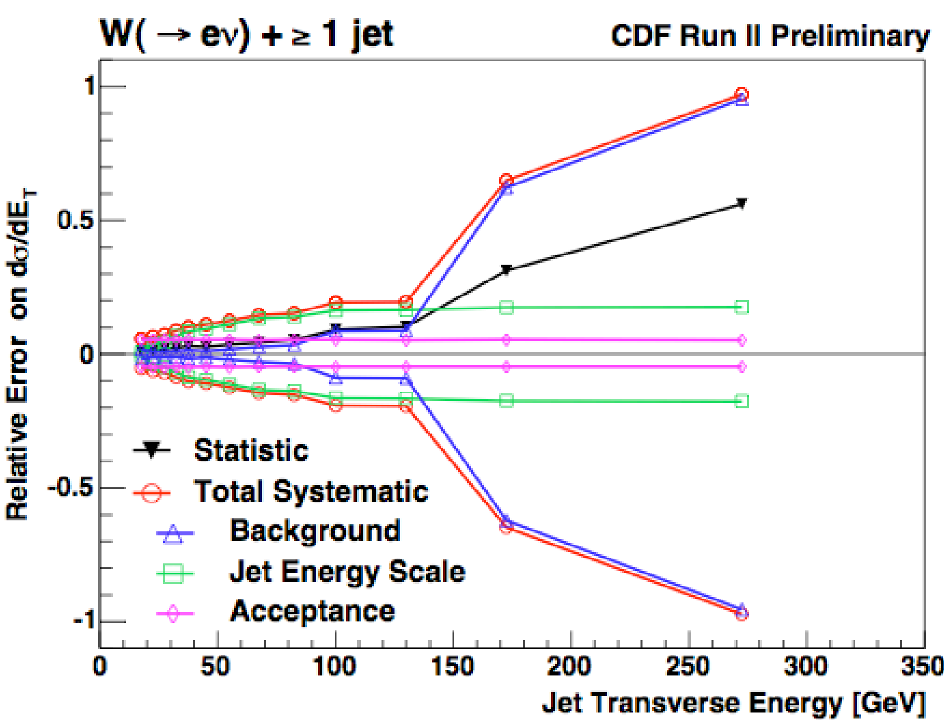


MC has been normalized to measured W+2 jet inclusive cross section!

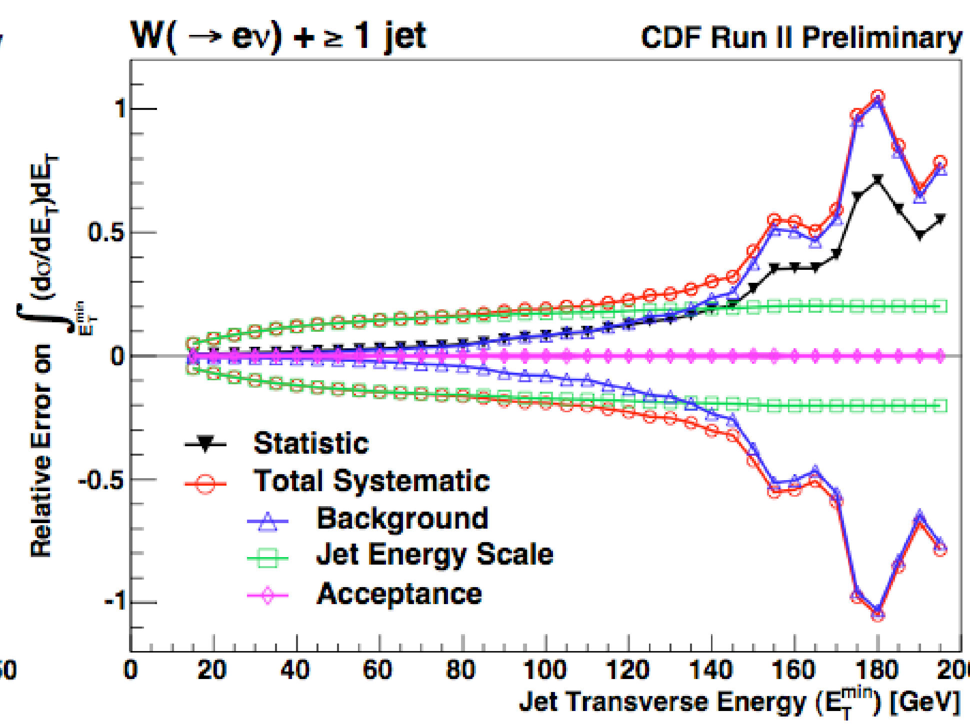
Errors breakdown

Representative of the behavior of errors in the measurements

Relative error on leading jet $d\sigma/dE_T$



Error on leading jet $\int(d\sigma/dET)dET$



- Large statistical uncertainty at large E_T.
- Systematic dominated by jet energy scale at low E_T, and by the (QCD) background subtraction at high E_T.

Work in progress and Plans

- Extend the measurement to use muons and to $1fb^{-1}$:
  - Larger E_T range, more sensitive to the tail of the cross-section.
  - Better control on data driven QCD background subtraction.
- Move to the preferred midpoint algorithm – don't expect big changes.

- Make extensive comparisons to theory, both shape and rate predictions:
  - LO ME-PS matching prescriptions – CKKW and MLM
  - NLO predictions: MCFM (parton level), MC@NLO (hadron level)

- Measure the Z + Jets cross-section:
  - Reduced statistics but backgrounds greatly reduced also.
  - Z + Jet events provide an alternative and cleaner environment for UE studies than multijet events.

Conclusions

- A new measurement of differential σ(W + jets) w.r.t jet kinematics, more suitable for theoretical comparisons:
  - Hadron level measurement: jet detector effects removed.
  - Differential measurement: background, acceptance and efficiency impact on shape accounted for.
  - Restricted W decay cross-section definition: reduced theoretical dependence.

- Any theorist can overlay their predictions without need for CDF detector simulation.

- The systematic on many high p_T measurements receives a substantial contribution from boson + jet knowledge.
- Crucial to have a robust simulation of boson + jets to explore for new physics at Tevatron & LHC.