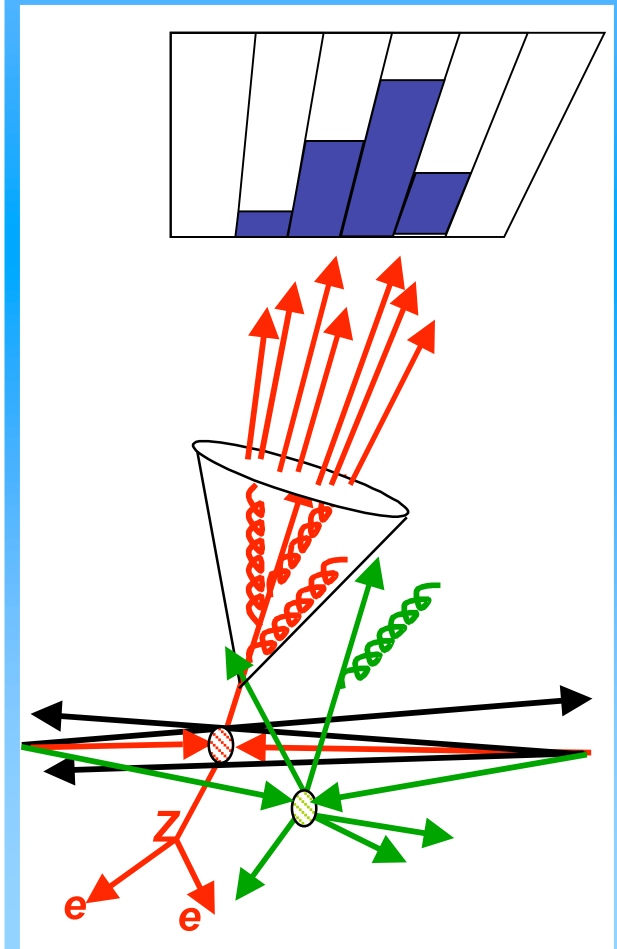
Measurements of Vector Bosons Produced in Association with Jets

Flavour inclusive only!



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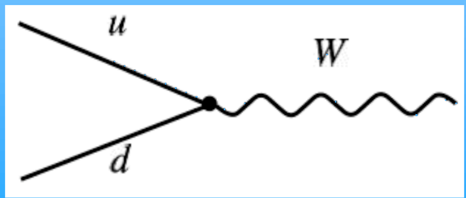
On behalf of the D0 and CDF collaborations

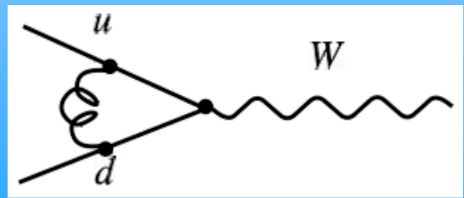
DIS 2008, 7th-11th April

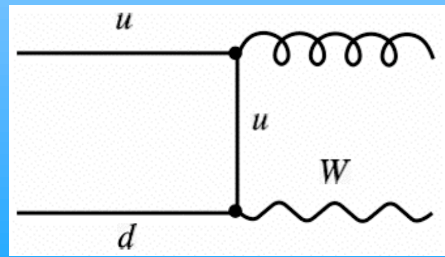
University College London

Why VB + Jets Measurements?

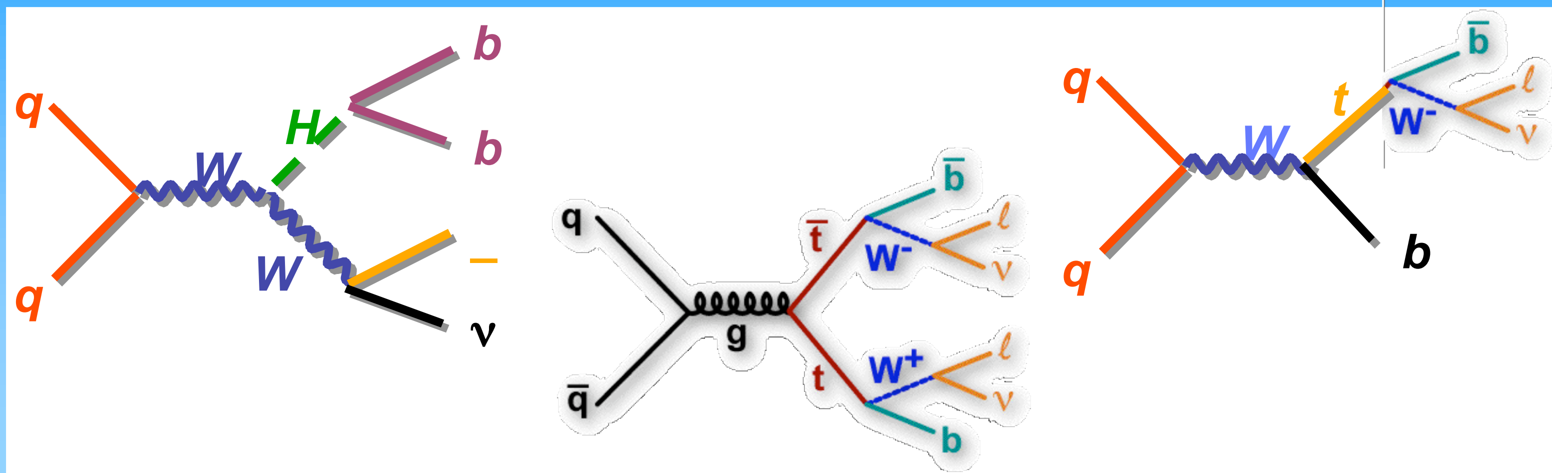
- Testing perturbative QCD predictions



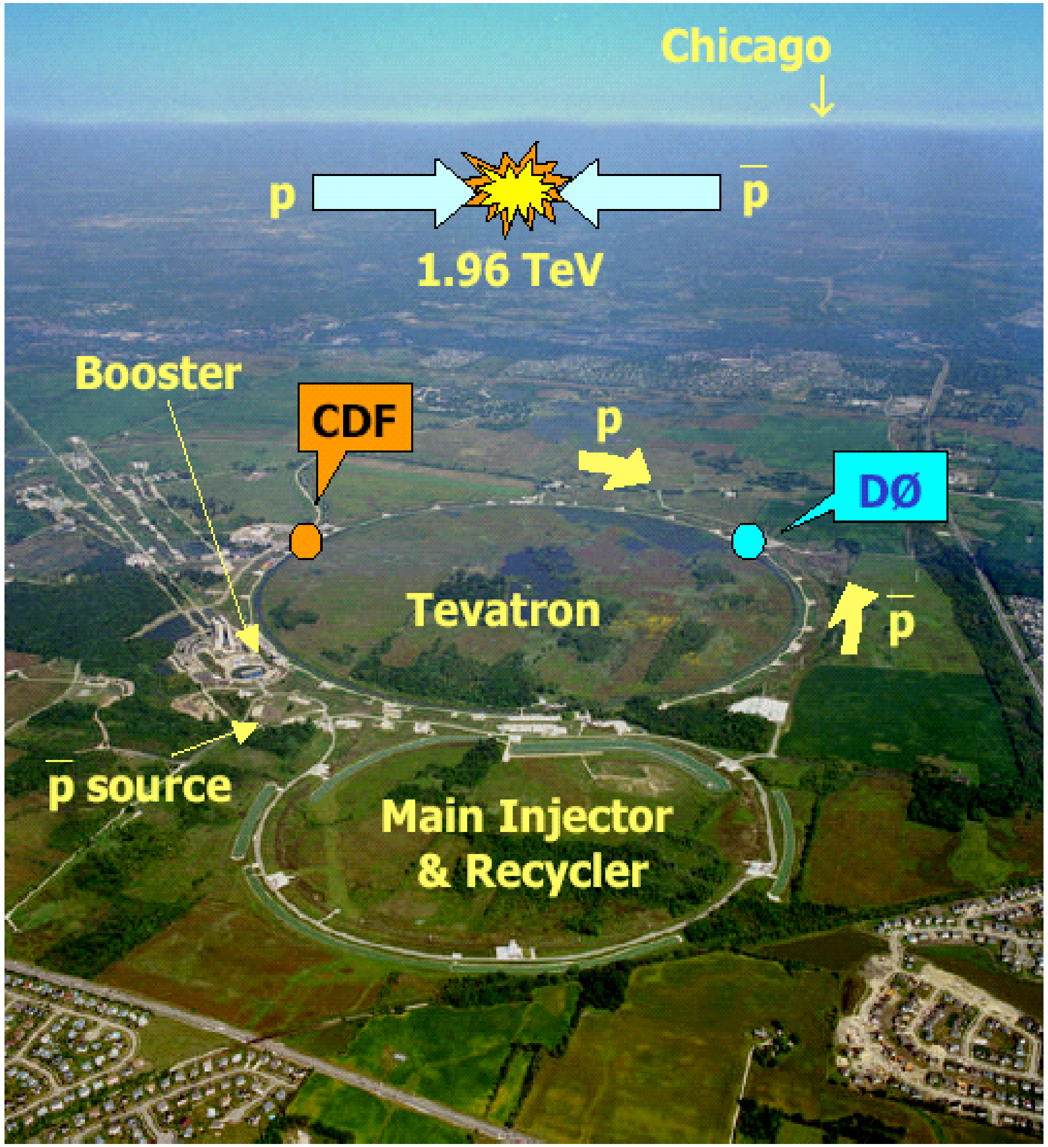




- Validation/Tuning of new LO-based models
- Shares common signature with many important processes: tt, single top, Higgs and SUSY searches



The Tevatron



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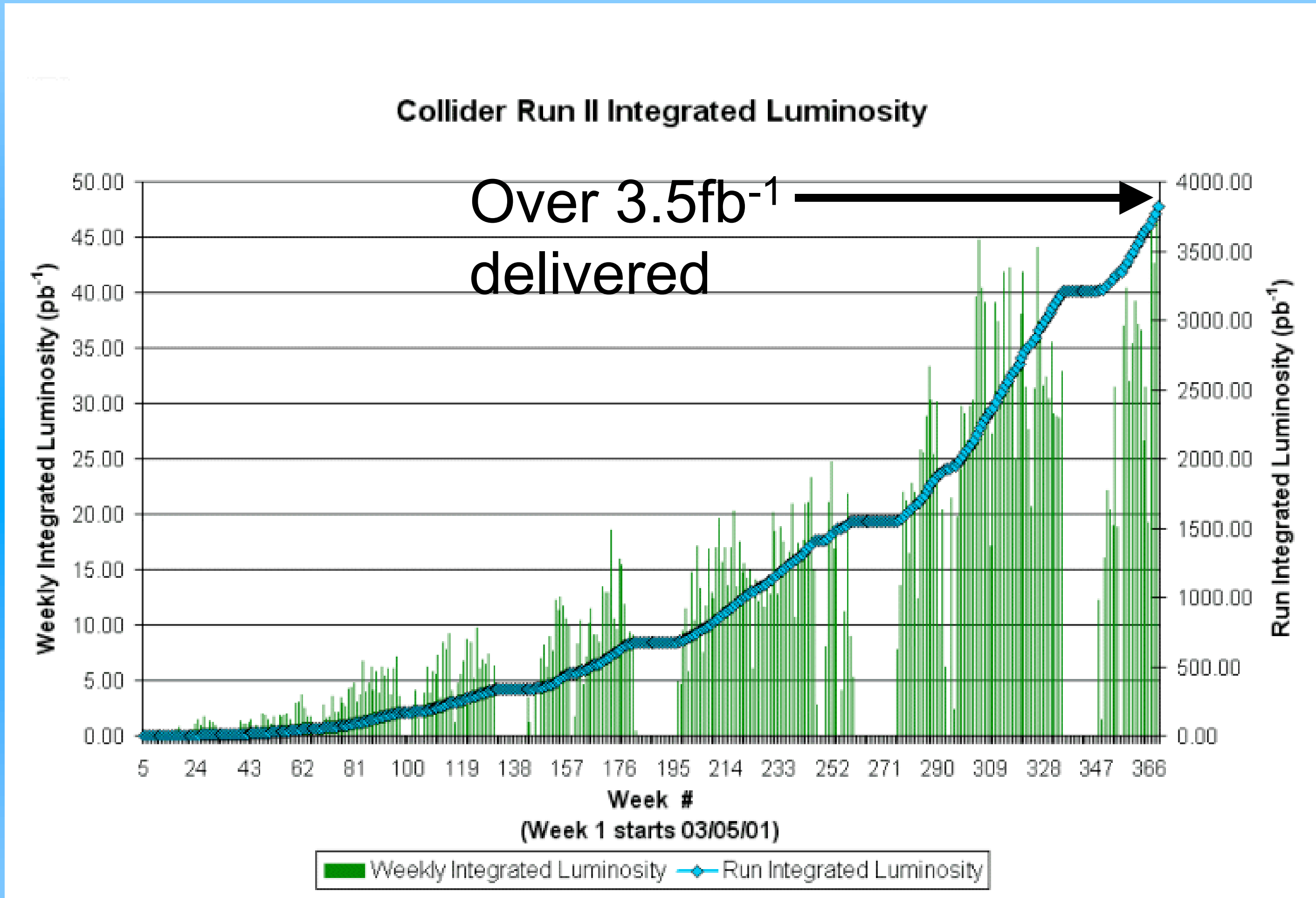
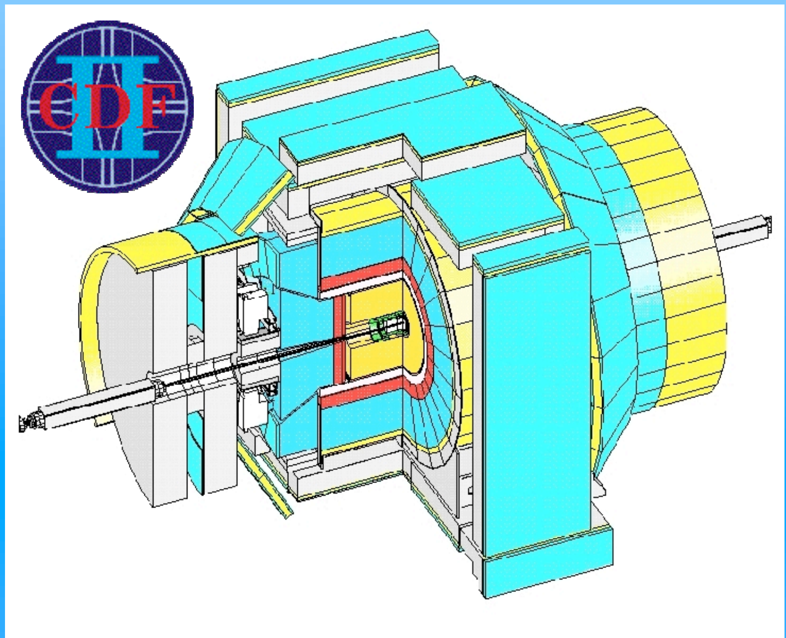
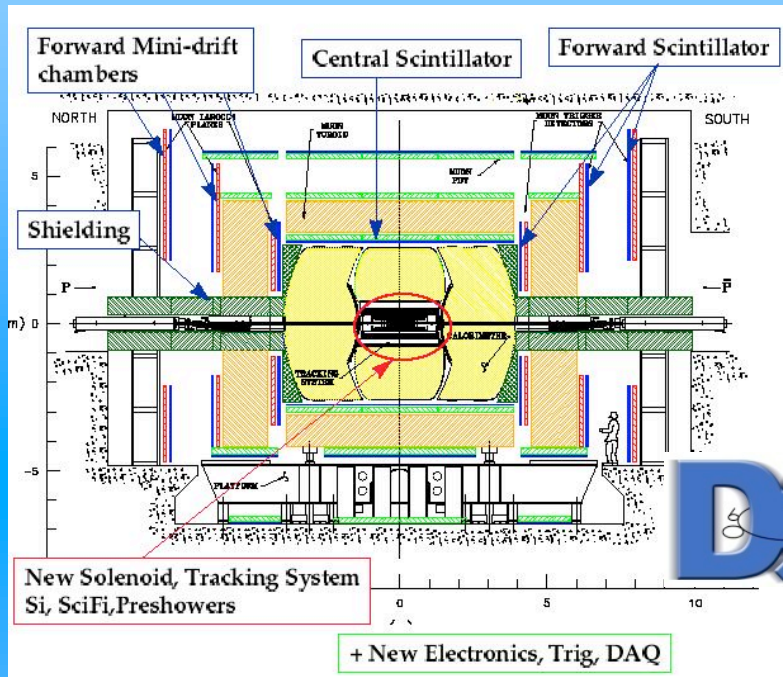


- Record luminosity 3.15 x $10^{32}cm^{-2}s^{-1}$ (design 2 x 10^{32})
- Expect to collect 6-8fb^{-1} by end Run II.

CDF and D0 Experiments

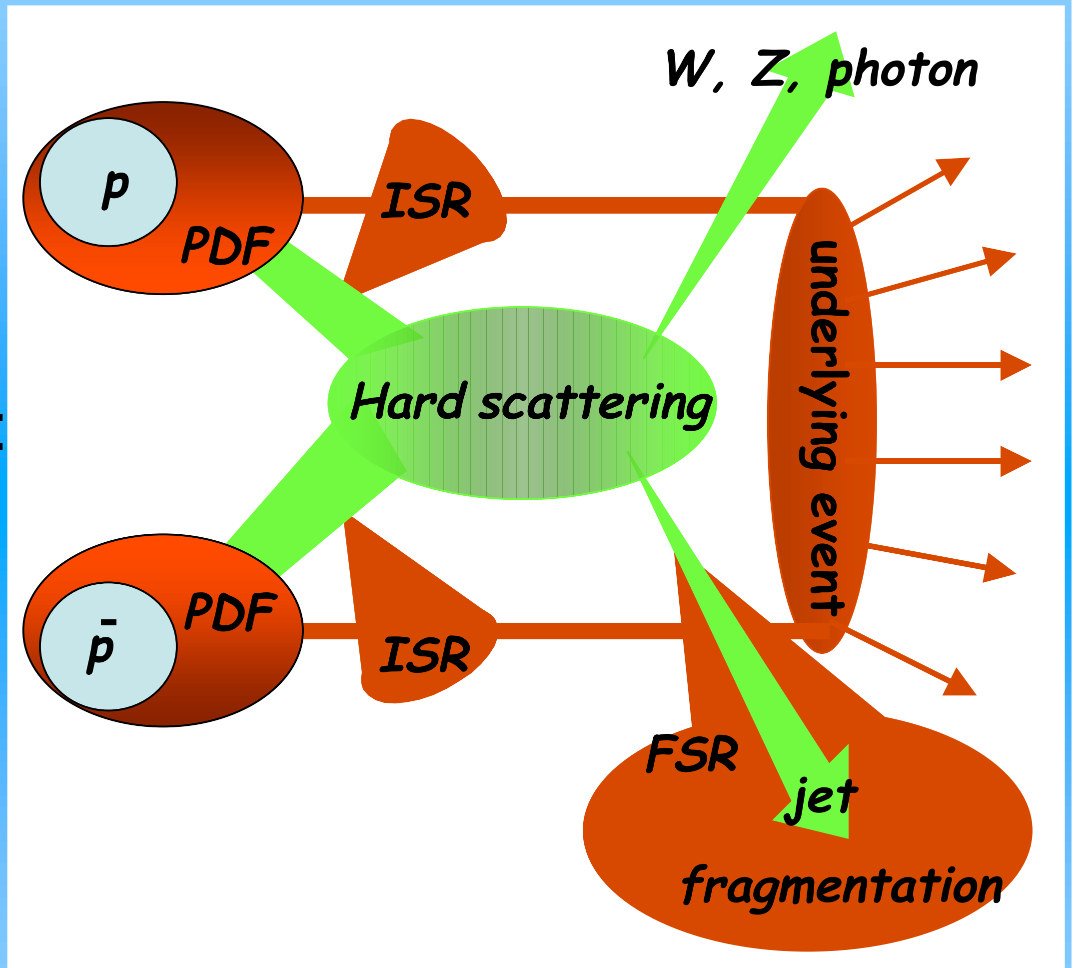




- Common features:
  - Charged particle tracking in a magnetic field
  - Electromagnetic and hadronic calorimetry
  - Dedicated muon detection chambers
  - Luminosity monitoring
  - Three level event triggering

Defining the Cross-Sections

- Have to choose a jet algorithm - cone, midpoint, K_T.
- Remove all detector/collider effects: JES, resolution, multiple pp interactions.
- At what level do we compare to theory?
- Hadron-level: include fragmentation and UE.



- Measure limited W/Z decay phase - reduce dependence on signal modelling in acceptance calculation.

ME-PS Matched Predictions

Matrix Element

- Fixed order calculation
- Valid for hard, well-separated partons
- Specify min parton P_T and ΔR cuts at LO

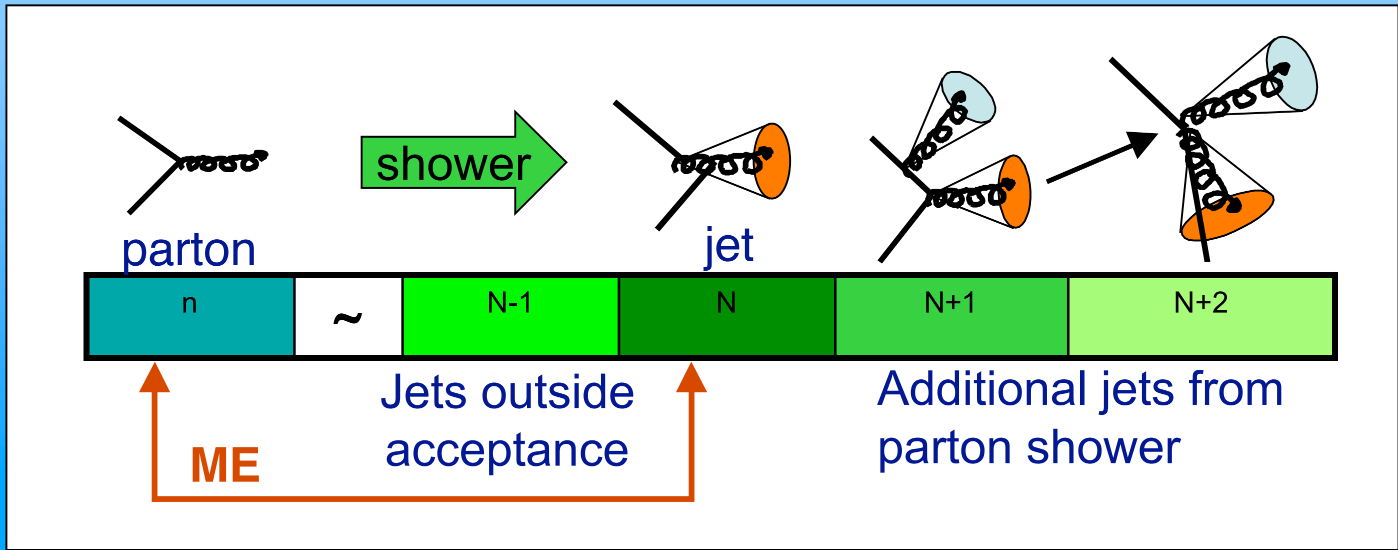
+

Parton Shower

- Leading log resummation
- Hadronisation model
- Valid for soft and/or collinear partons

- NLO predictions 1,2 jet only: MCFM (parton), MC@NLO
- ME-PS Matching schemes: CKKW and MLM
  - Allow combination of W + np LO ME-PS generations without double counting. Large phase space coverage.
  - Reduces dependence on parton-level cuts.
- Available in number of generators: Alpgen, MadEvent, Sherpa, Helac, Ariadne.

ME-PS Matched Predictions



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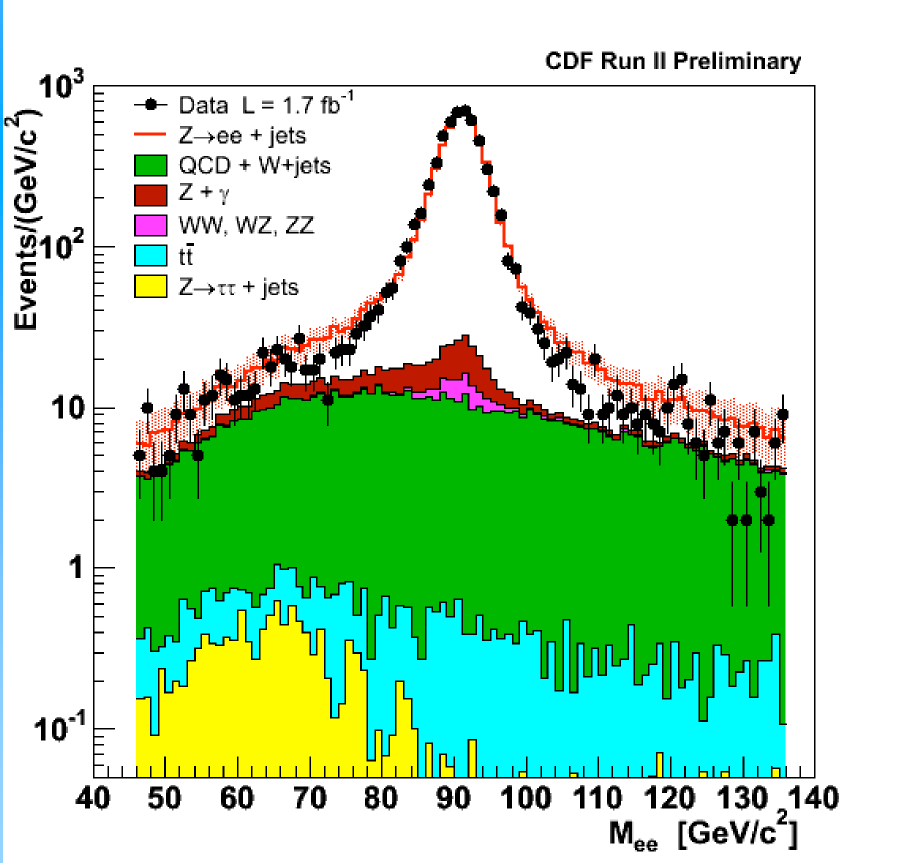
1.7fb^{-1}

Z/γ^* + Jets

- Identify $Z \rightarrow e^+e^-$ events:
  - Two E_T > 25 GeV electrons
  - $|\eta^e| < 1.0$ or $1.2 < |\eta^e| < 1.8$
  - $66 < M_{ee} < 116$ GeV/c^2
  - $\Delta R(e,jet) > 0.7$
- Backgrounds are small:
  - 12% -17%.
  - Dominated by QCD/W+Jets - estimated from data.
  - Other backgrounds from MC.

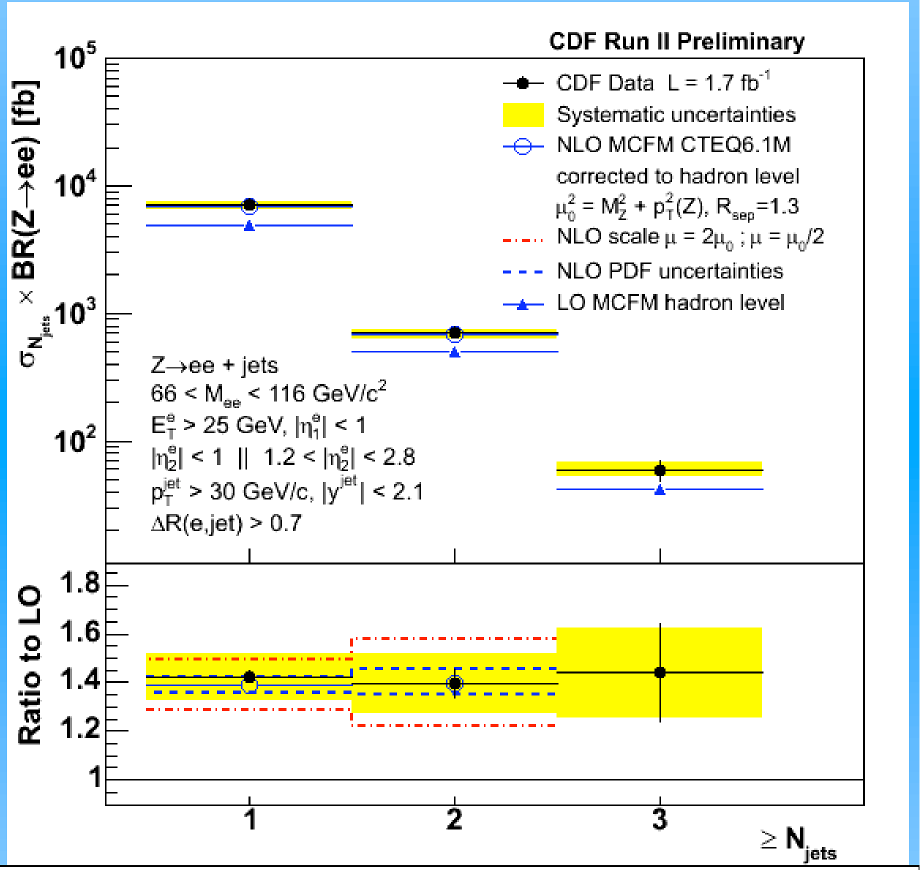
→ Cross-section defined for this limited decay phase space.



1.7fb^{-1}

Z/γ^* + Jets

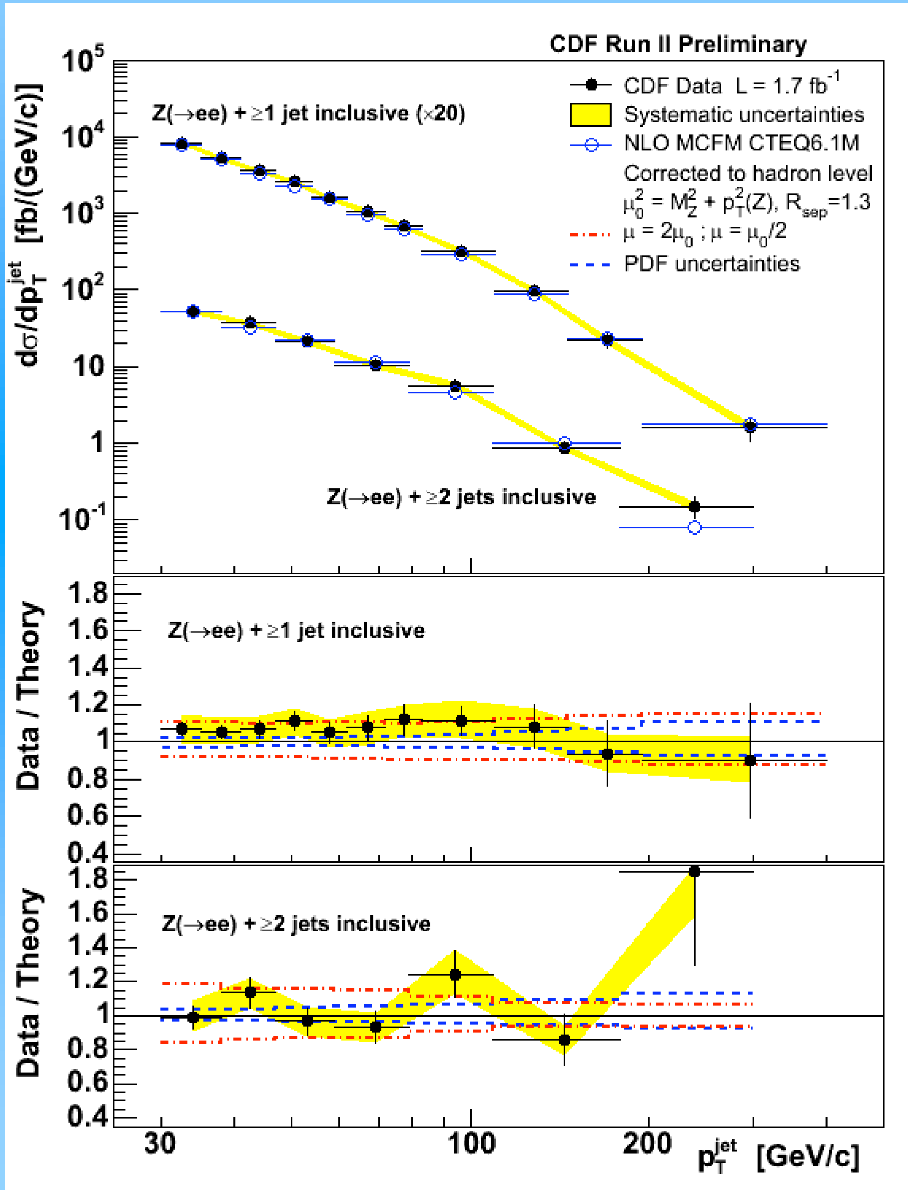
- Jet definition:
  - Midpoint cone 0.7
  - Jet P_T > 30 GeV/c, |y| < 2.1
  - Corrected to hadron-level
- Compare to MCFM LO and NLO (1j,2j only) predictions:
  - Predictions include parton-hadron correction factors.
- NLO gives excellent prediction of njet rate.
- NLO/LO K-Factor ~ 1.4.



$\sigma(Z + \geq n \text{ jet}; P_T^{min} > 30 \text{ GeV})$

1.7fb^{-1}

Z/γ* + Jets



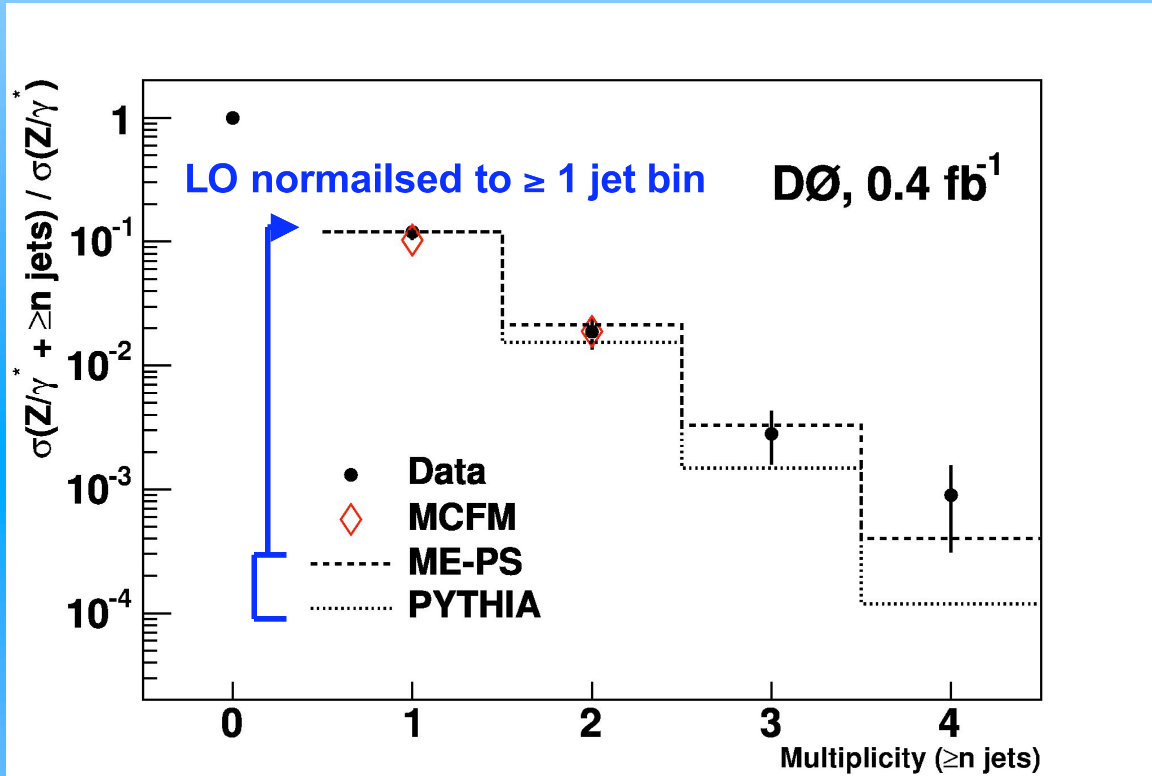
Inclusive Z+≥1 Jet and Z+≥2 Jets cross-section as function of P_T^{jet} (sys. errors correlated)

- NLO well reproduces dependence with P_T^{jet}
- Statistics are limited at high P_T^{jet}
- Also measured as function of nth P_T^{jet} and y^{jet}.

400pb^{-1}

Z/γ^* + Jets

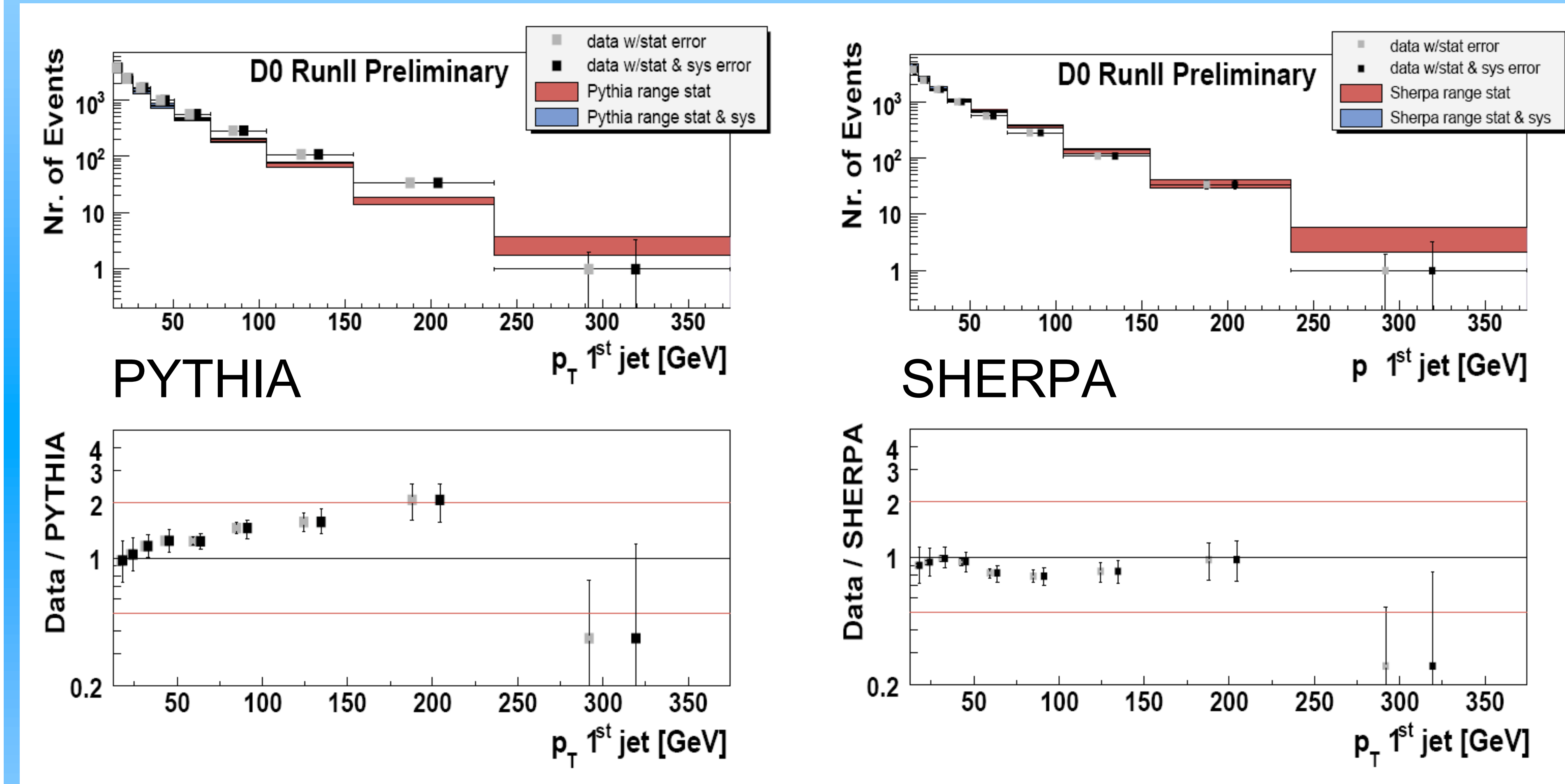
- Corrected back to full cross-section for $75 < M_{ee} < 105$ GeV/c^2.
- Jet Definition:
  - Seeded cone 0.5
  - $P_T > 20$ GeV
  - $|\eta| < 2.5$



- Jets corrected to the hadron-level.
- Measured ratio $\sigma(Z/\gamma^* + \text{jets})/\sigma(Z/\gamma^*)$.
- Comparison to NLO (parton), ME-PS matched and PYTHIA.

950pb^{-1}

Z/γ^* + Jets



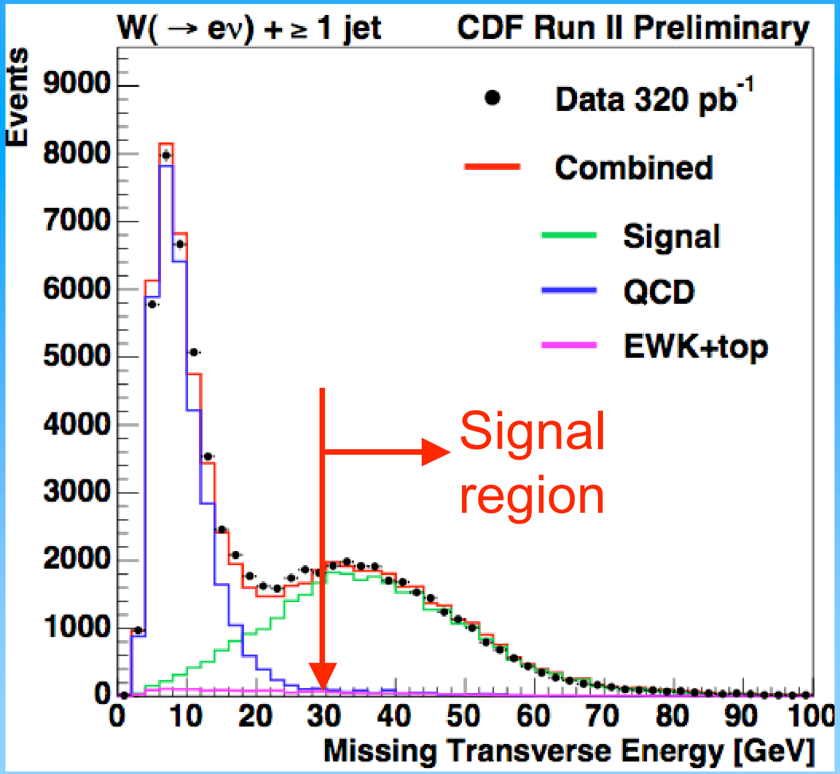
- Shape comparisons to data event yield distributions.
- ME-PS matched predictions of Sherpa are better!

W + Jets

320pb^{-1}

- Identify $W \rightarrow e\nu$ events:
  - Electron E_T > 20 GeV
  - $|\eta^e|$ < 1.1
  - Missing E_T > 30 GeV
  - W M_T > 20 GeV/c^2
- Backgrounds are large:
  - Low E_T^{jet} 10-40%
  - High E_T^{jet} 90%
  - Dominated by QCD multijets, but t-tbar important also at higher jet multiplicities.
- Multijet background determined from data.

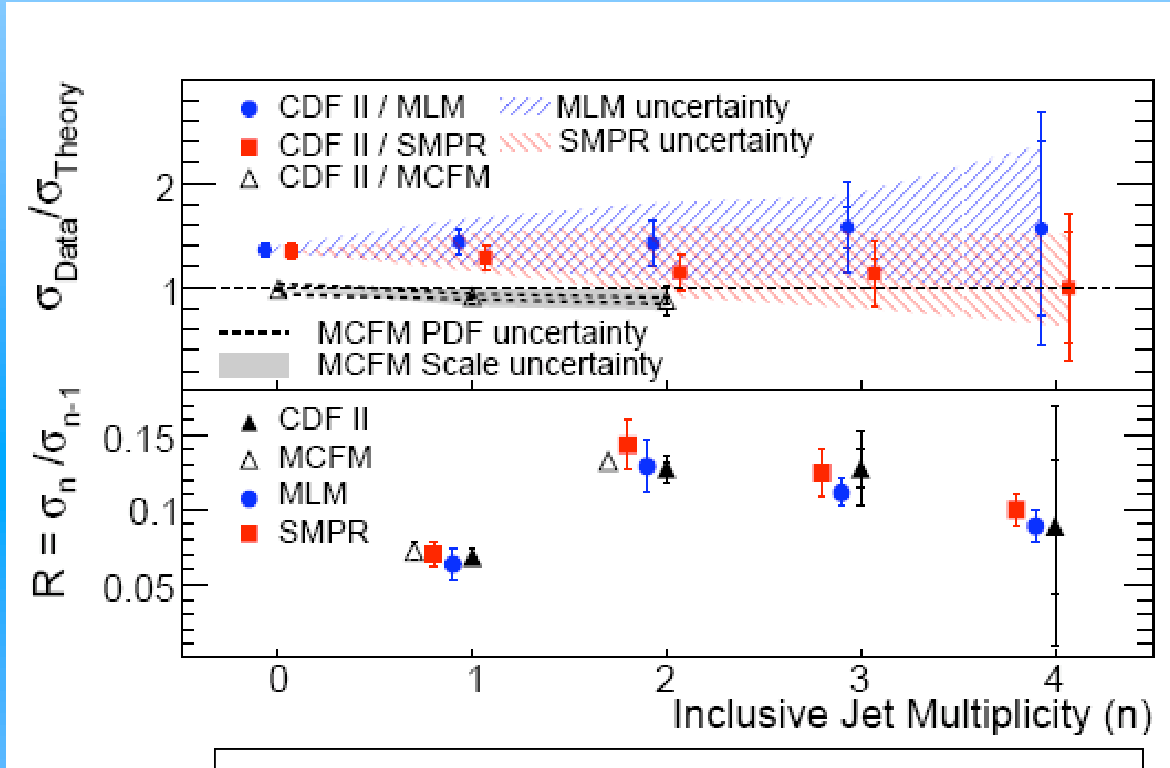
→ Cross-section defined for this limited decay phase space.



320pb^{-1}

W + Jets

- Jet definition:
  - Seeded cone 0.4
  - Jet E_T > 20 GeV, $|\eta|$ < 2.0
  - Corrected to hadron-level.
- Compare to MCFM NLO
  - No parton-hadron corrections.



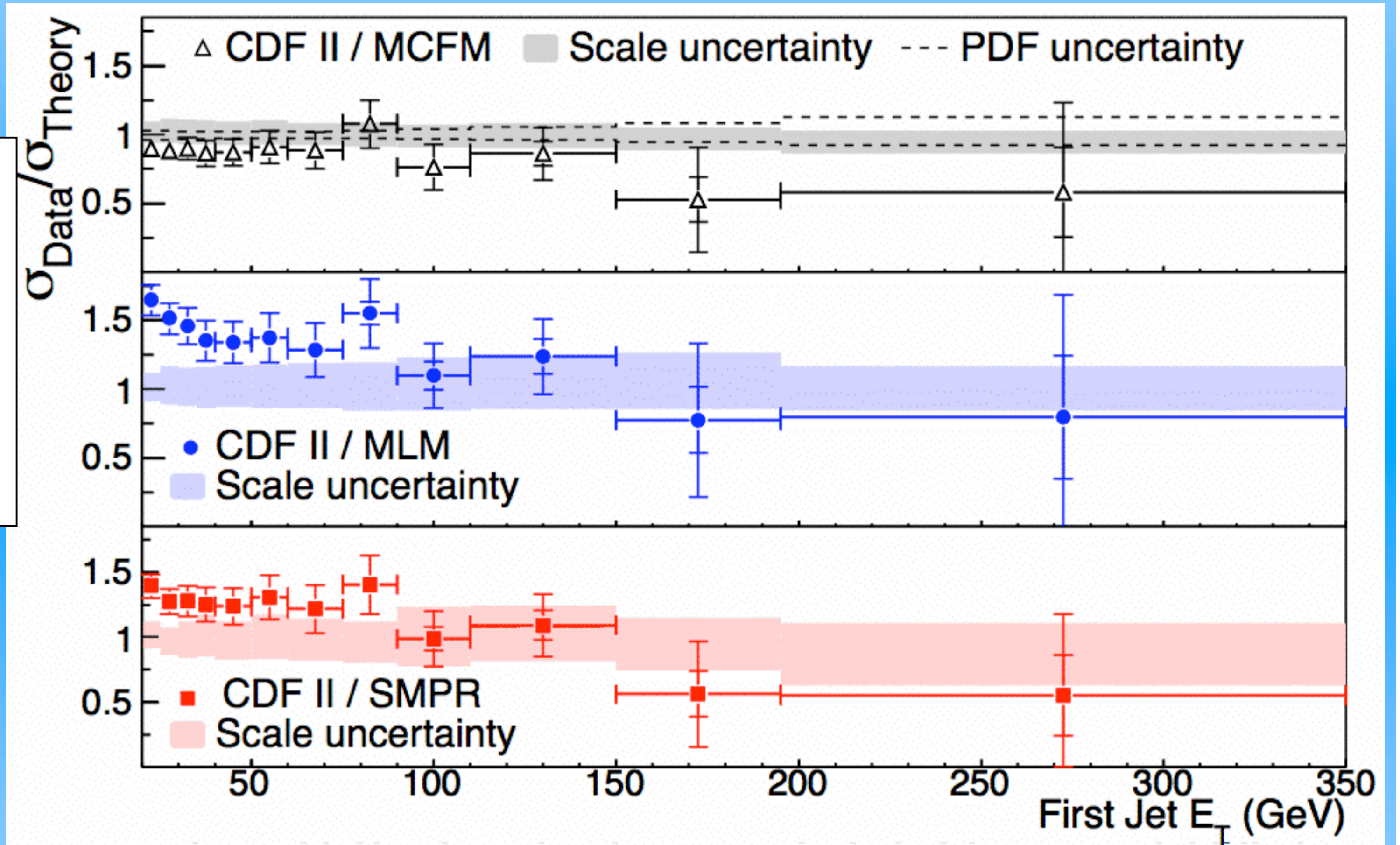
$\sigma(W + \geq n \text{ jet}; E_T^{min} > 25 \text{ GeV})$

- Compare to LO ME-PS matched Madgraph+Pythia and Alpgen+Herwig (NOT normalised to data).
- NLO/LO K-factor ~ 1.4.

320pb^{-1}

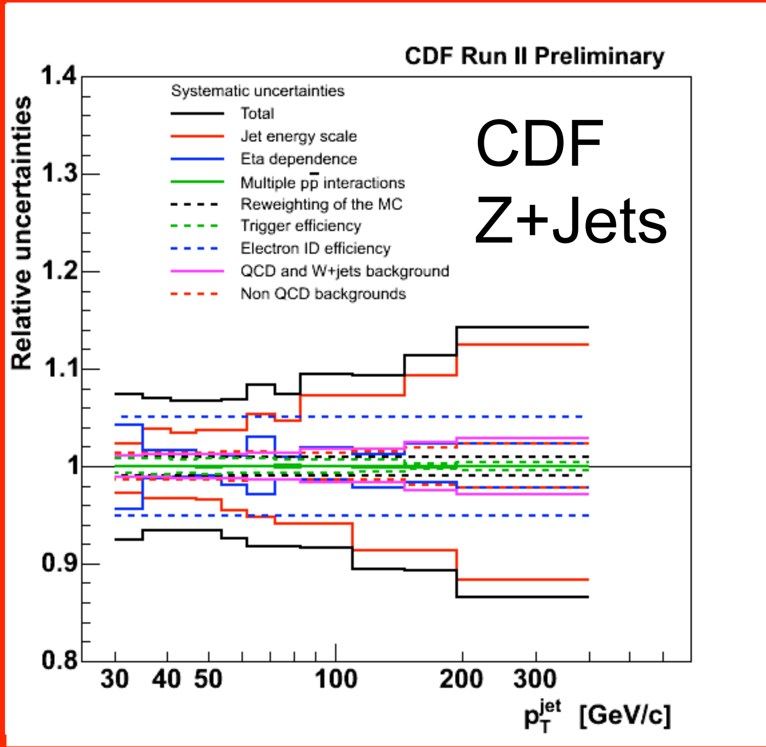
W + Jets

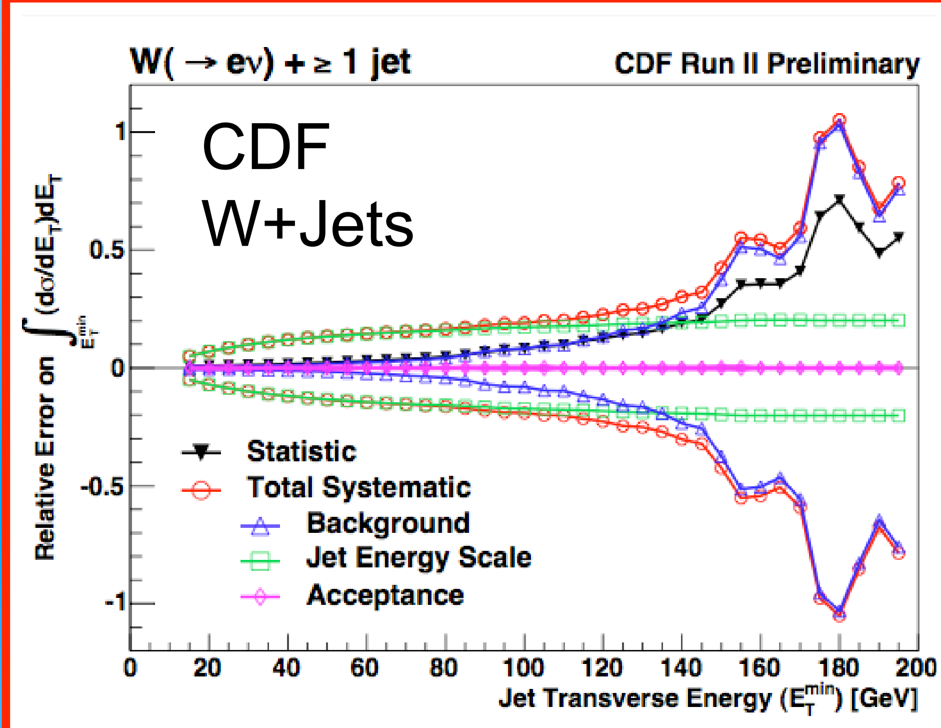
Differential W+≥1 jet cross-section as function of lead jet E_T



- Uncorrected NLO agrees to within 10%!
- Difference in performance of two ME-PS predictions.

Systematics





Multiplicity ($Z/\gamma^* + \geq n$ jets)	$n \geq 1$	$n \geq 2$	$n \geq 3$	$n \geq 4$
R_n	120.1	18.6	2.8	0.90
Total Statistical Uncertainty	±3.3	±1.4	±0.56	±0.44
Total Systematic Uncertainty	−17.1, +15.6	−5.0, +6.2	−1.06, +1.43	−0.40, +0.48
Jet Energy Calibration	±11.7	±3.3	±0.74	±0.23
Jet Reconstruction/Identification	−7.0, +2.2	−2.9, +4.3	−0.64, +0.82	−0.30, +0.40
Unsmearing Procedure	−3.6, +2.2	−1.6, +2.4	−0.24, +0.85	−0.08, +0.09
Jet Energy Resolution	−2.7, +3.4	−0.04, +0.13	−0.17, +0.15	−0.03, +0.04
Acceptance	±1.8	±0.7	±0.10	±0.003
Efficiencies (Trigger, EM, Track)	±8.5	±1.3	±0.20	±0.07
Electron-Jet-Overlap	±3.2	±0.7	±0.14	±0.05

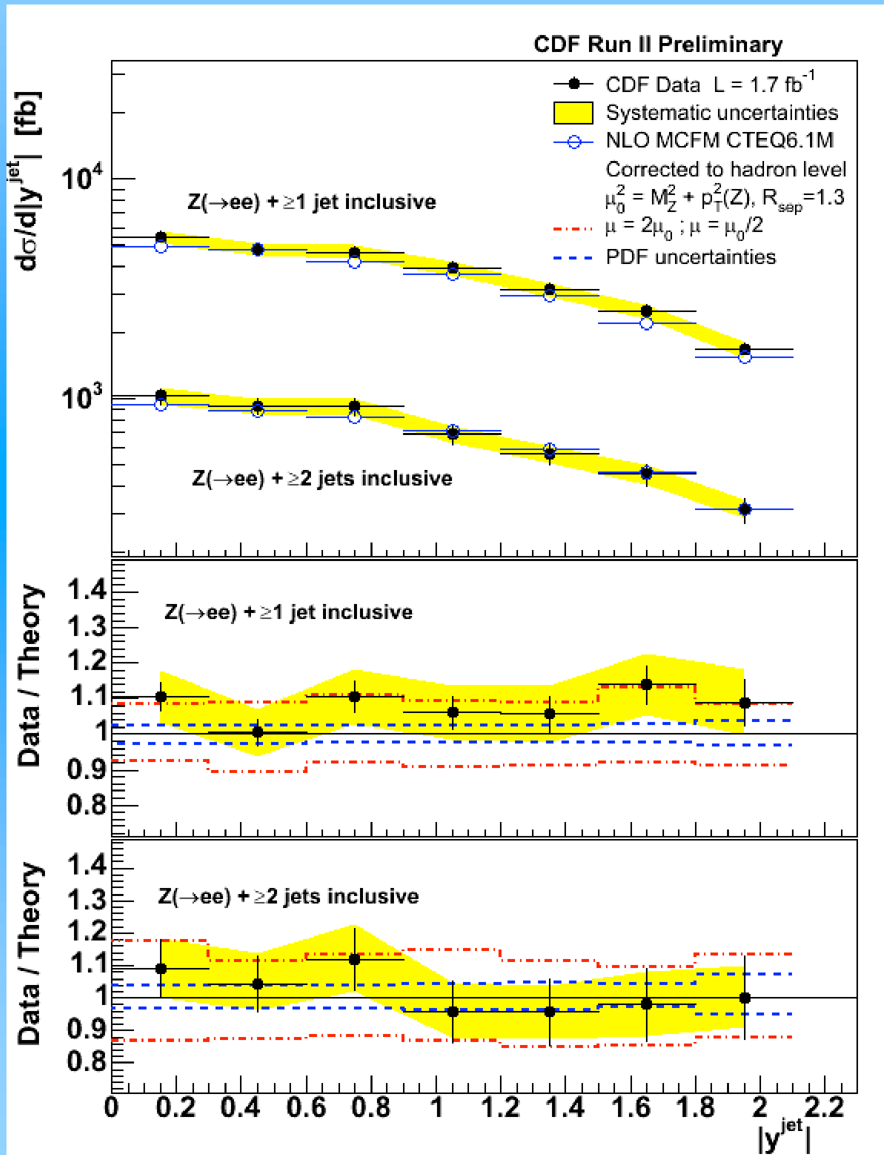
D0
Z+Jets

Summary & Conclusions

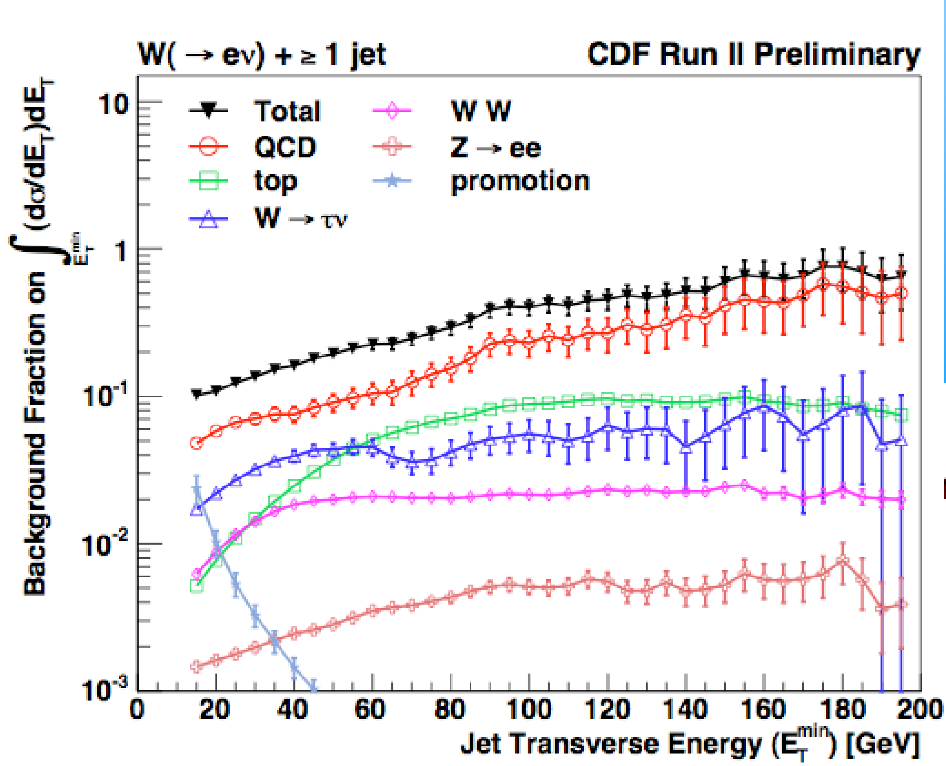
- A good understanding of the W/Z + Jets process is crucial at the Tevatron and LHC.
- NLO predictions of W/Z + Jets show excellent agreement with measurements.
- But only available for 1,2 jets…
- …need ME-PS matched predictions to model higher multiplicities
- Latest Tevatron measurements give opportunity to validate and tune these approaches - this work is really just beginning…
- …how well will these findings extrapolate to the LHC?

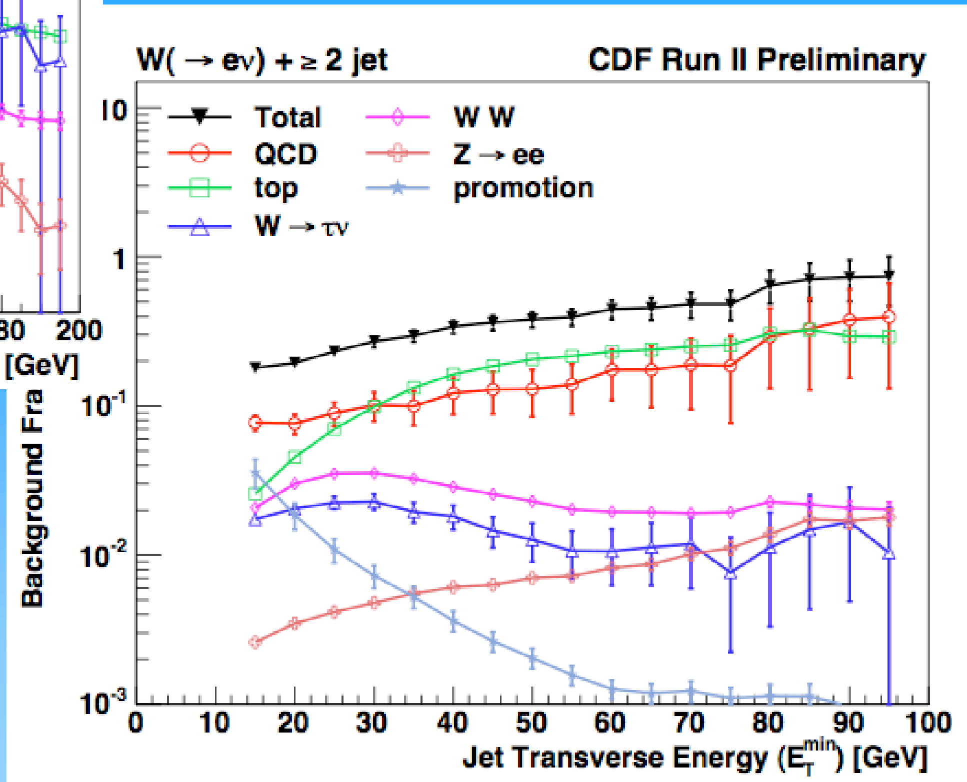
Backups

Z + Jets y^{jet} Results

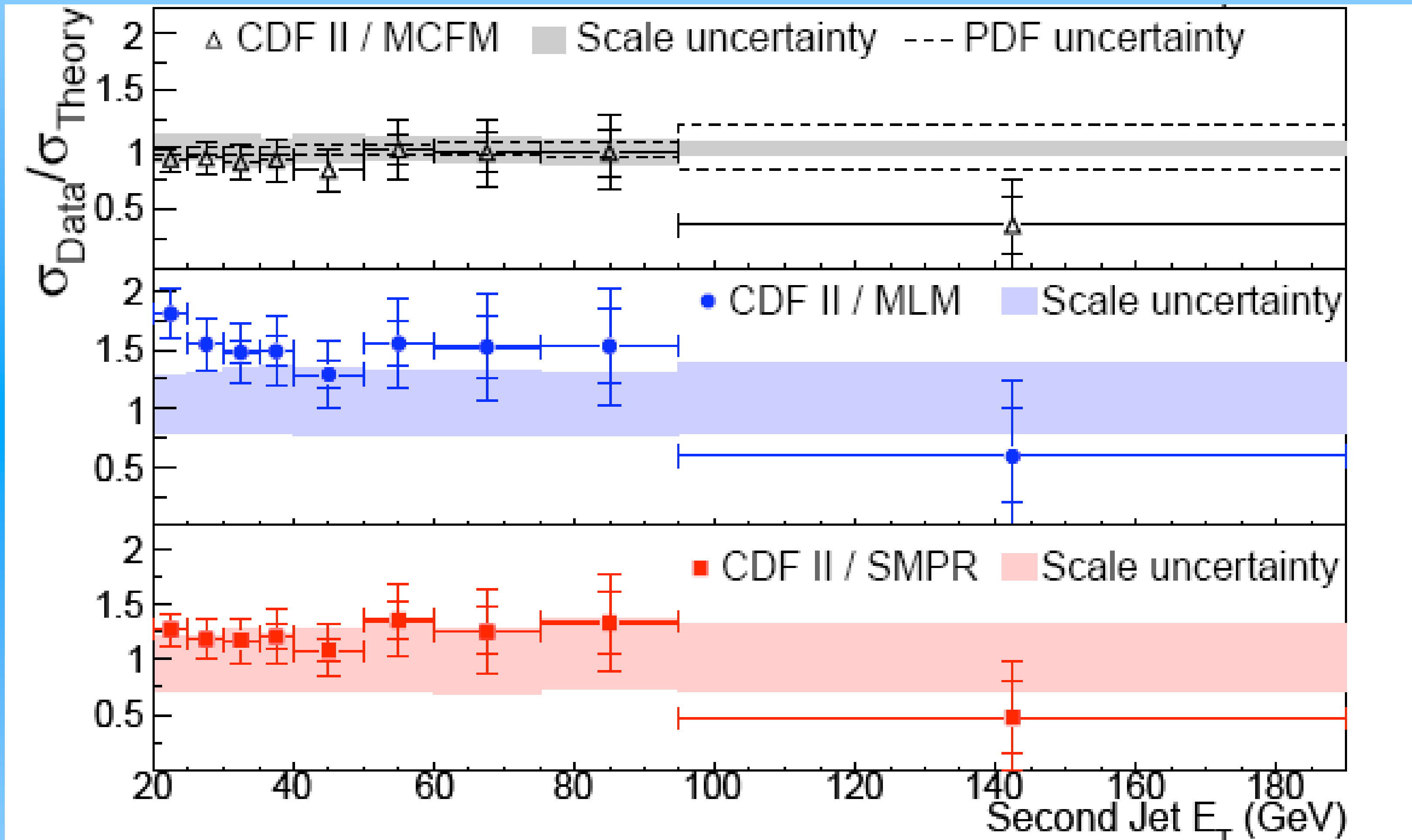


W + Jets Backgrounds





W+Jets Second Jet



W+Jets Third Jet