MC Validation for V+jets Production

OUTLINE

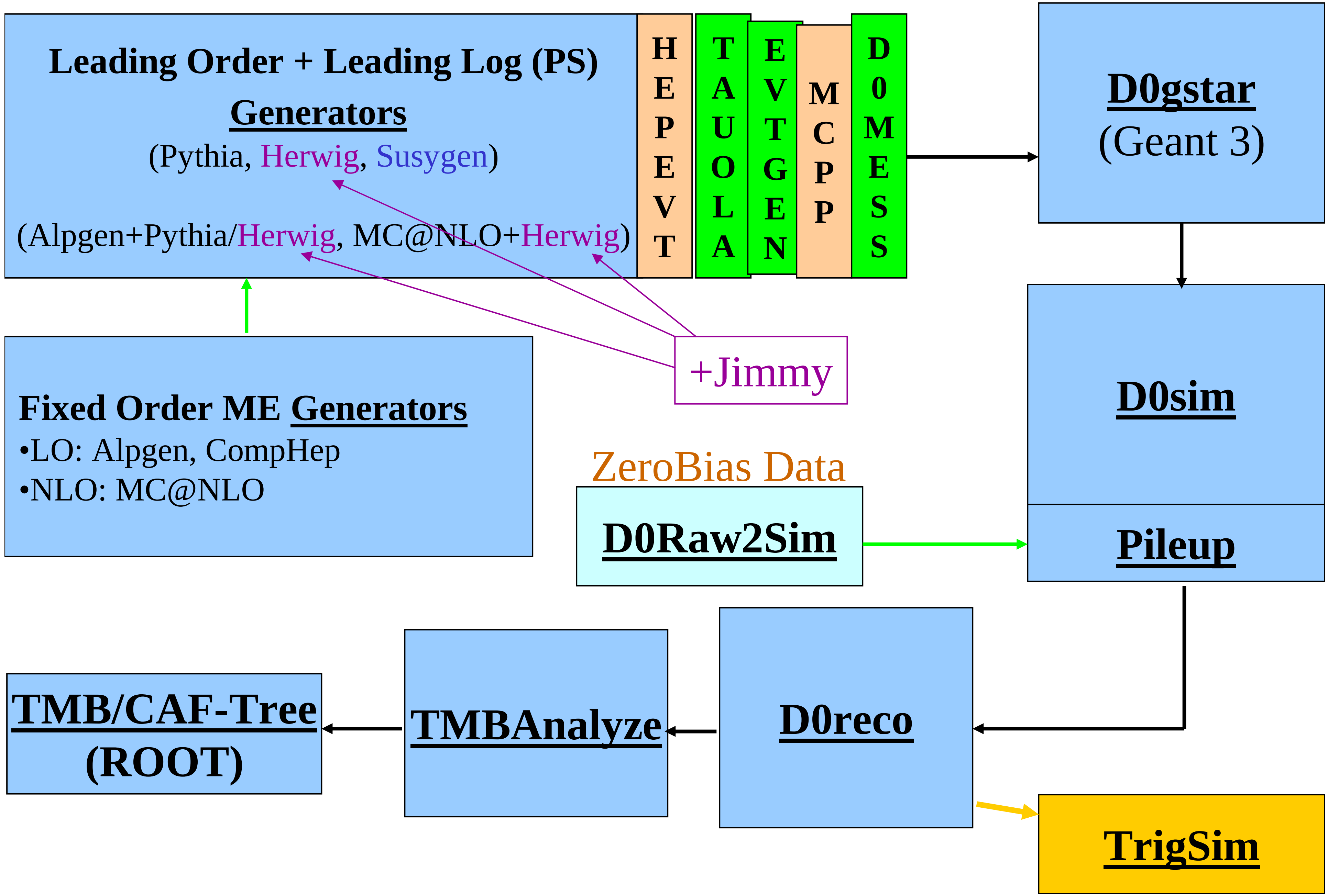
I. Introduction
II. "Soft Physics" Tunes
III. Testing ME-PS Matching
IV. V+Heavy Flavor Quark(s)
V. Conclusions

Introduction

- **What are the important features to get a reliable description of the V+jets phenomenology at Hadron Colliders?**

- Need to get both hard (ME pQCD) and soft physics (resummation, UE,…) right, plus correct values for flavor ratios (V+HF-jets / V+LF-jets)
  - Shapes: different variables depend on different ingredients
    - Resummation → $p_T(V)$ => JES, bkgd kinematics, mE_T calibration,…
    - ME → Multijet topologies: N_{jets}, p_T(jets), $\Delta\phi(j,j')$, $\Delta R(j,j')$,…
    - HF fractions: depend on heavy quarks PDFs, $\mathcal{P}(g \to QQ)$, FF, (exp) HF-jets tagging
  - Normalizations:
    - Need at least NLO (QCD)
    - Some NNLO (QCD) results are available, but might have to check against NLO (EW) in certain regions of phase space!!!
    - Might normalize directly on data in some cases
- Don't forget this is also an experimental challenge:
  - Have to rely on an accurate detector simulation (dead material, realistic and time dependent noise and dead/bad channels maps,…)
  - Have to rely on a good trigger simulation (or to measure trigger efficiencies in data)

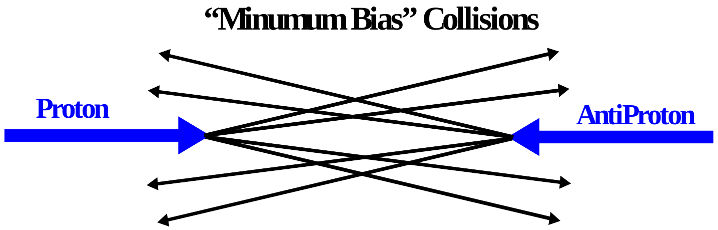
Introduction



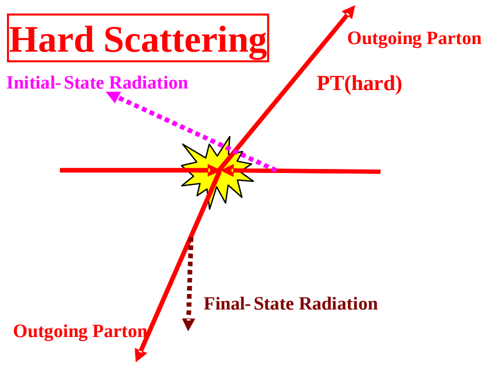
Soft Physics Tunes: Underlying Event

R. Field, CDF

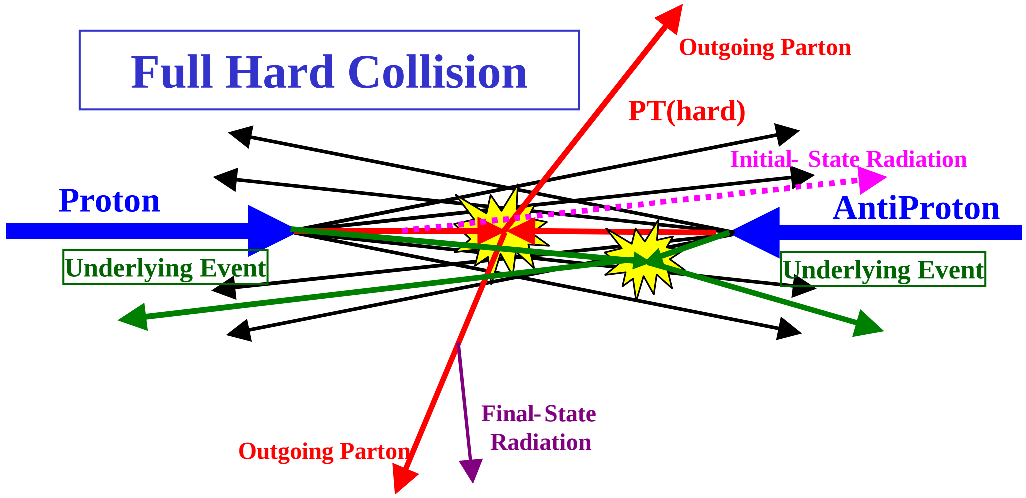
Minimum Bias Collision



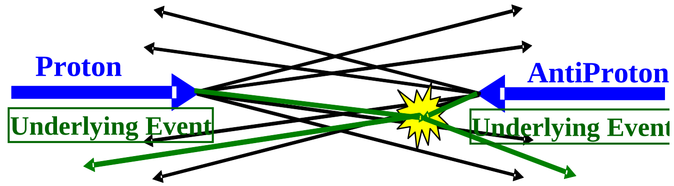
Hard Scattering



Full Hard Collision



Underlying Event



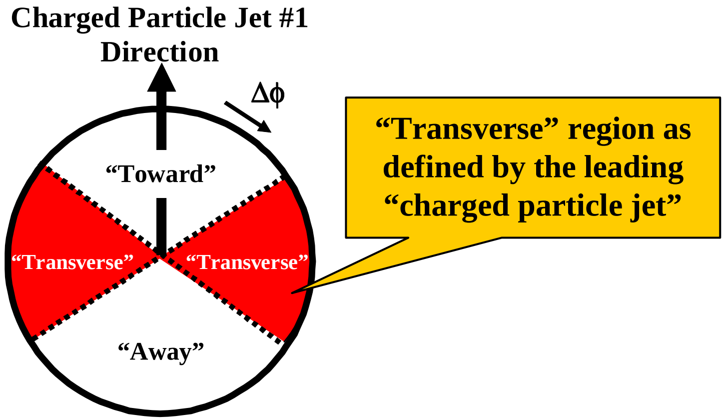
Note: MPI contributes mainly to soft physics just because it occurs at $Q_{2nadry} << Q_{hard\ scatt}$, but it's still a perturbative process

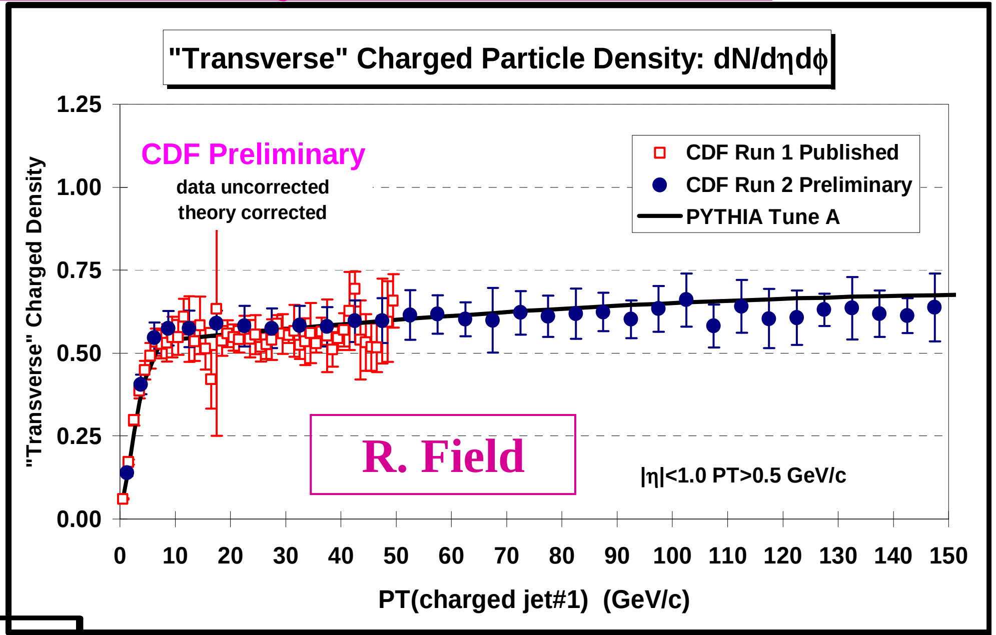
Some Definitions

- **MI:** **multiple pp or ppbar collisions in a given bunch crossing**
- **MPI:** **multiple parton interactions in a given pp or ppbar collision**
- **Minimum Bias:**
  - **it's a trigger condition (not a physics process)**
  - **low p_T QCD, (SD single arm), DD are the contributing sub-processes**
  - **Note: UE in most hard collisions also fire this trigger term**
- **UE:** **interactions of spectator partons, including possible MPI**
- **Pile-Up:**
  - **Definition: signals overlapping in time in a sub-detetctor**
  - **Consequence: may add up events from different bunch crossings**
  - **It's a detector issue, not a physics process, nor a trigger condition!**

Soft Physics Tunes: Underlying Event

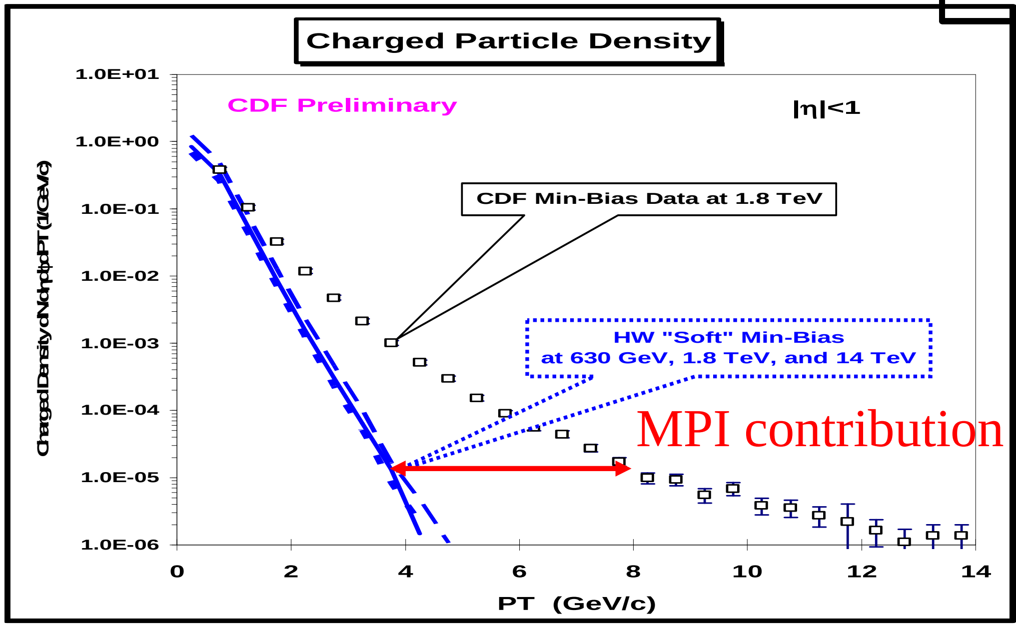
Transverse Charged Particle Density vs CDF Run I/II





- Compares the Run 2 data (Min-Bias, JET20, JET50, JET70, JET100) with Run I

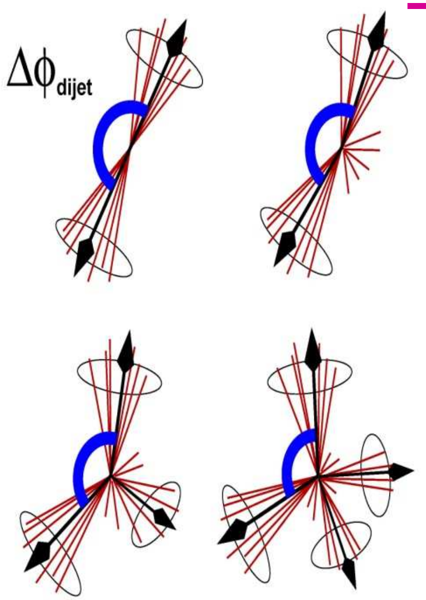
Also works for RunII data



MPI contribution to UE cannot be neglected!!!

Soft Physics Tunes: Underlying Event

Dijet Decorrelation vs D0 Run II



- **Jet Algo:**

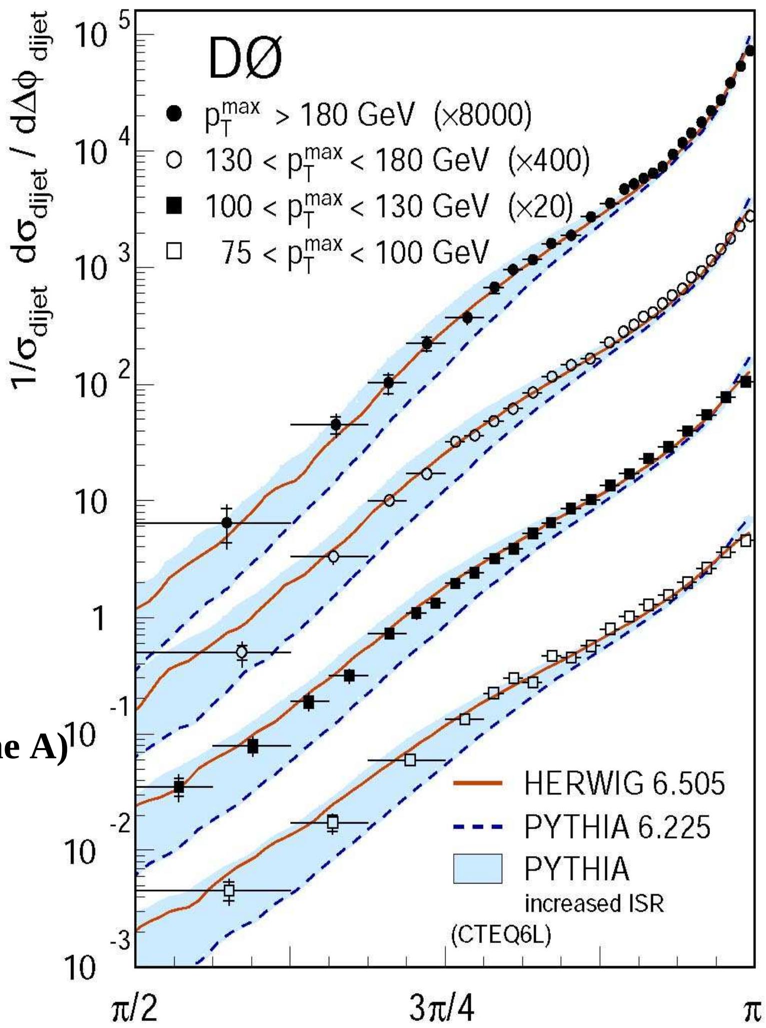
MidPoint Cone, ΔR = 0.7

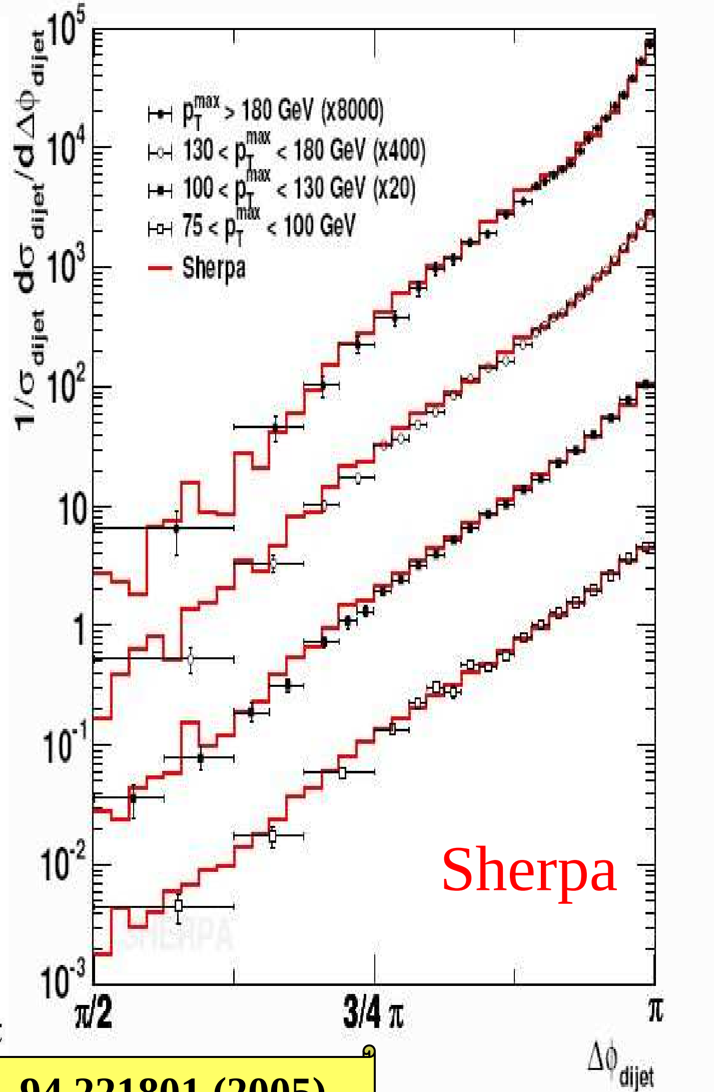
- **PYTHIA ISR:**

PARP(67)=2.5 (4.0 for Tune A)

$$\int \mathcal{L}dt = 0.15\, fb^{-1}$$

Δφ(j₁,j₂)



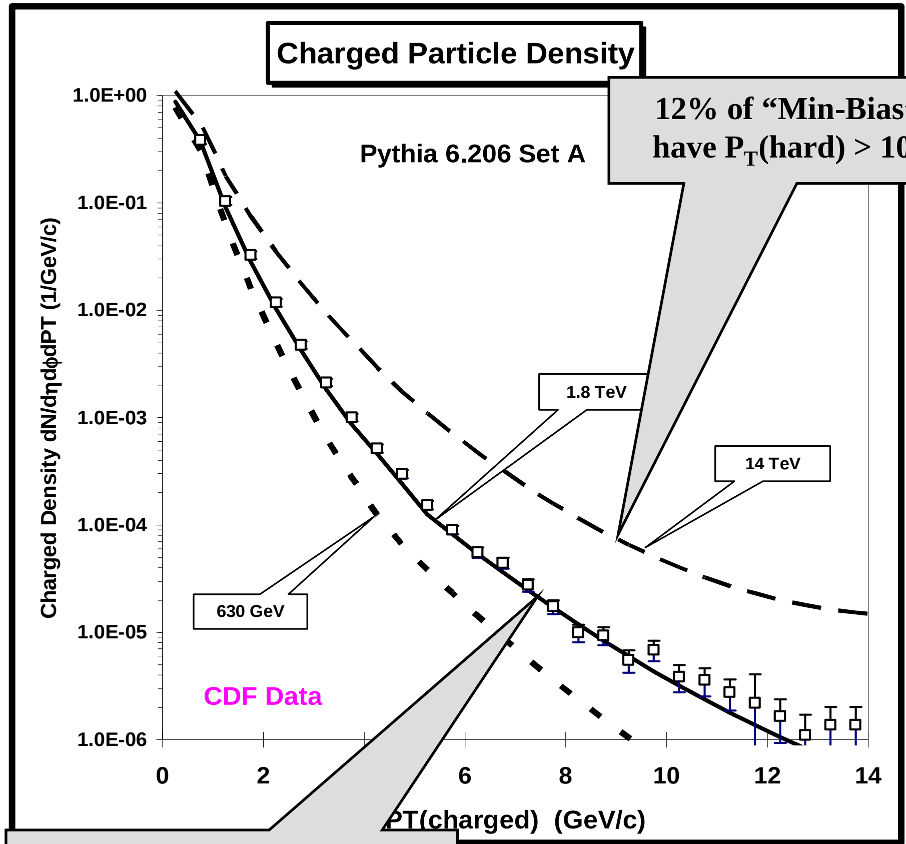


Phys. Rev. Lett. 94 221801 (2005)

Soft Physics Tunes: Underlying Event

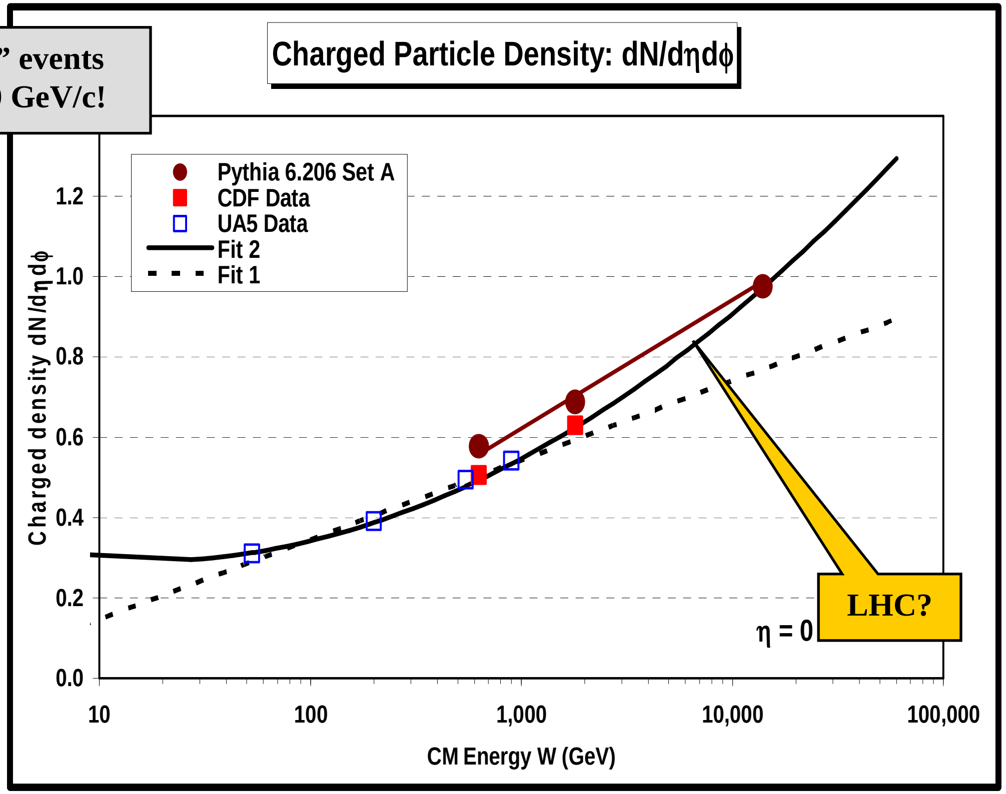
UE Extrapolation from Tevatron to LHC

R. Field



12% of "Min-Bias" events have P_T(hard) > 10 GeV/c!

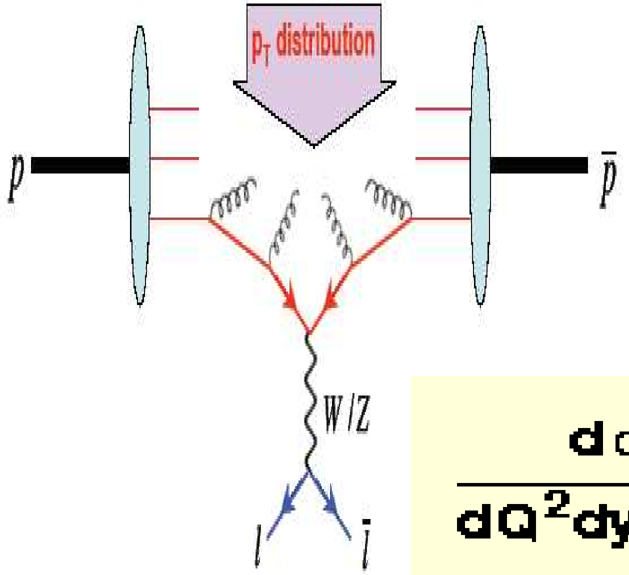
1% of "Min-Bias" events have P_T(hard) > 10 GeV/c!



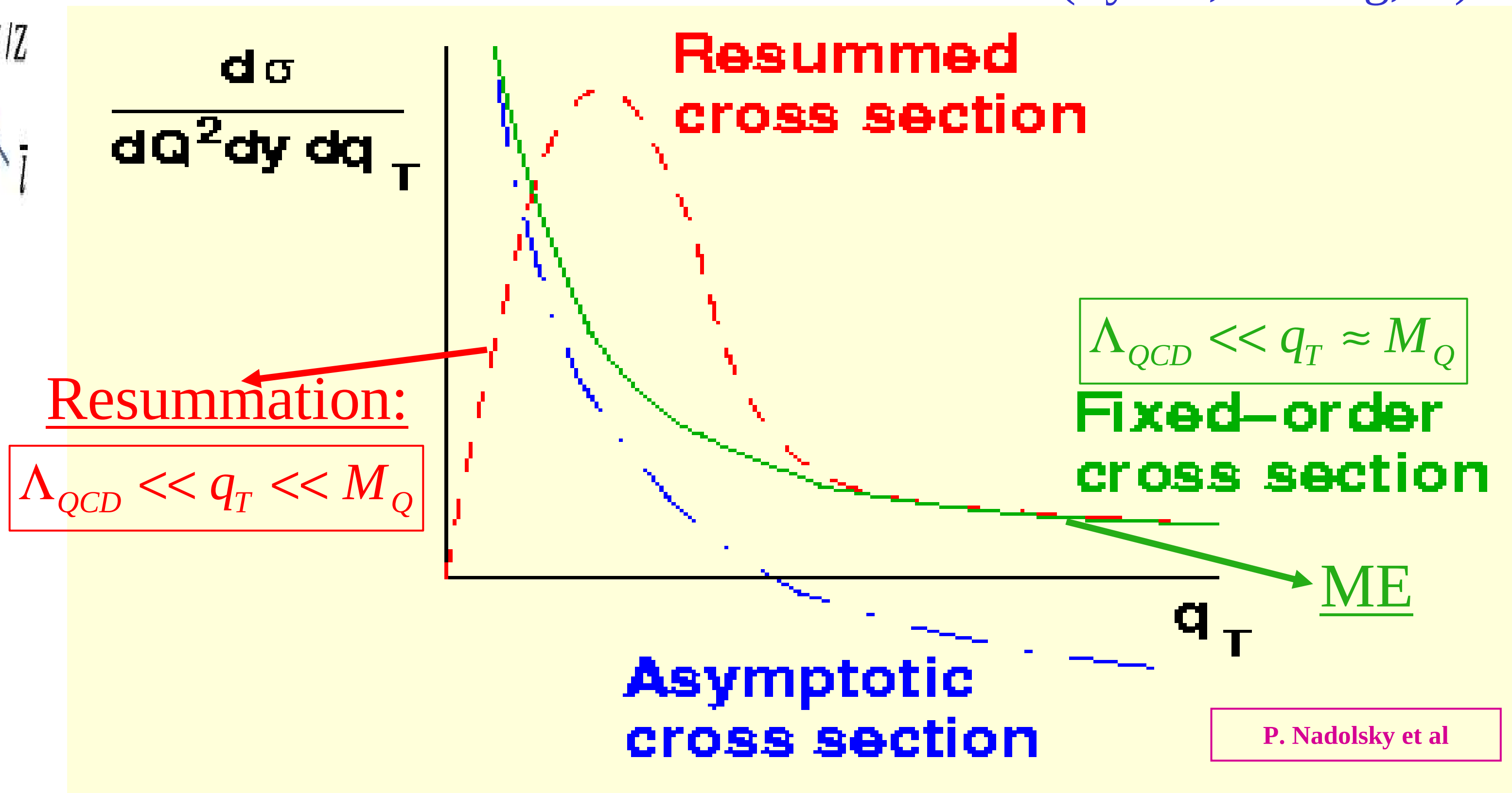
UE is much harder at the LHC than at the TEVATRON!!!

But, large uncertainties in the extrapolation => will have to re-tune UE on LHC data!!!

Soft Physics Tunes: q_T Resummation



- FO calculations: reliable only if all scales ~ same order
- Origin: multiple soft gluon emissions
- If Q' >> Q => terms like **$[\alpha_S Ln^2(Q'/Q)]^n$** @ all orders!
- Implementation:
  - Analytical (CSS formalism,…)
  - Parton Shower (Pythia, Herwig,…)



Soft Physics Tunes: UE and q_T Resum.

UE and p_T(V) from PS vs CDF Run I

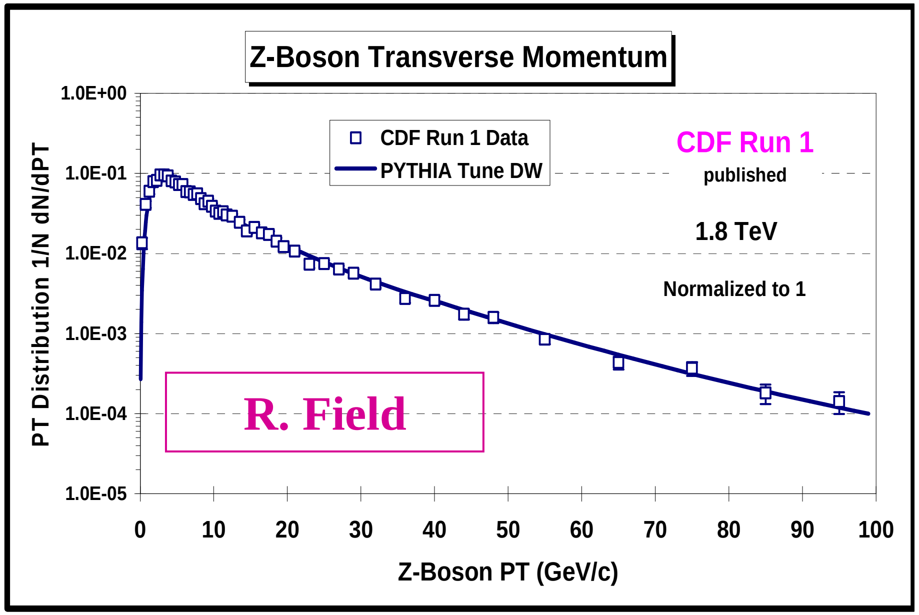
PYTHIA 6.2

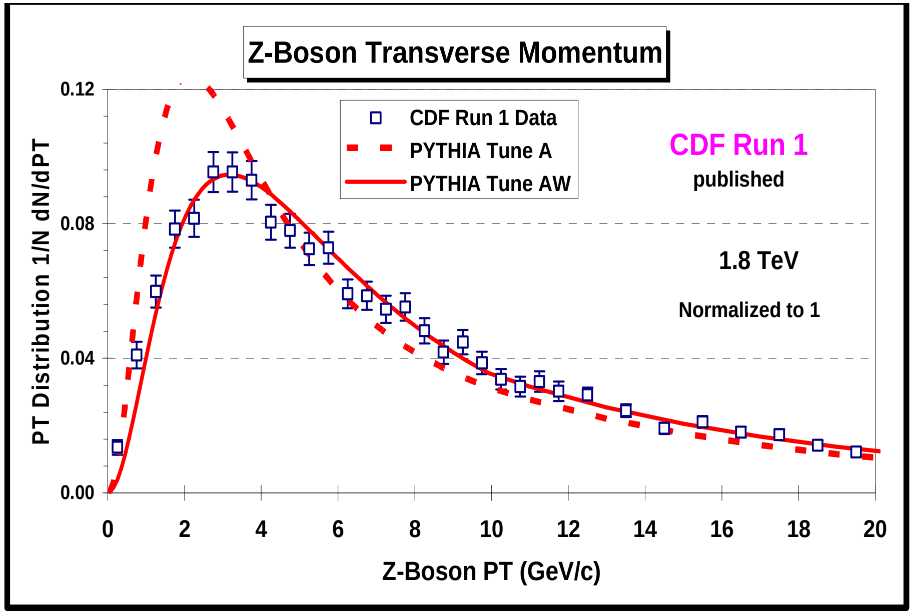
Parameter	Tune A / AW	Tune DW / DWT	Tune QW
PDF	CTEQ5L	CTEQ5L	CTEQ6.1M
MSTP(81)	1	1	1
MSTP(82)	4	4	4
PARP(82)	2.0 GeV	1.9 / 1.9409 GeV	1.1 GeV
PARP(83)	0.5	0.5	0.5
PARP(84)	0.4	0.4	0.4
PARP(85)	0.9	1.0	1.0
PARP(86)	0.95	1.0	1.0
PARP(89)	1.8 TeV	1.8 / 1.96 TeV	1.8 TeV
PARP(90)	0.25	0.25 / 0.16	0.25
PARP(62)	1.0 / 1.25	1.25	1.25
PARP(64)	1.0 / 0.2	0.2	0.2
PARP(67)	4.0	2.5	2.5
MSTP(91)	1	1	1
PARP(91)	1.0 / 2.1	2.1	2.1
PARP(93)	5.0 / 15.0	15.0	15.0

UE: MSTP(81) – PARP(90)

ISR: PARP(62) – PARP(67)

Intr. k_T: MSTP(91) – PARP(93)





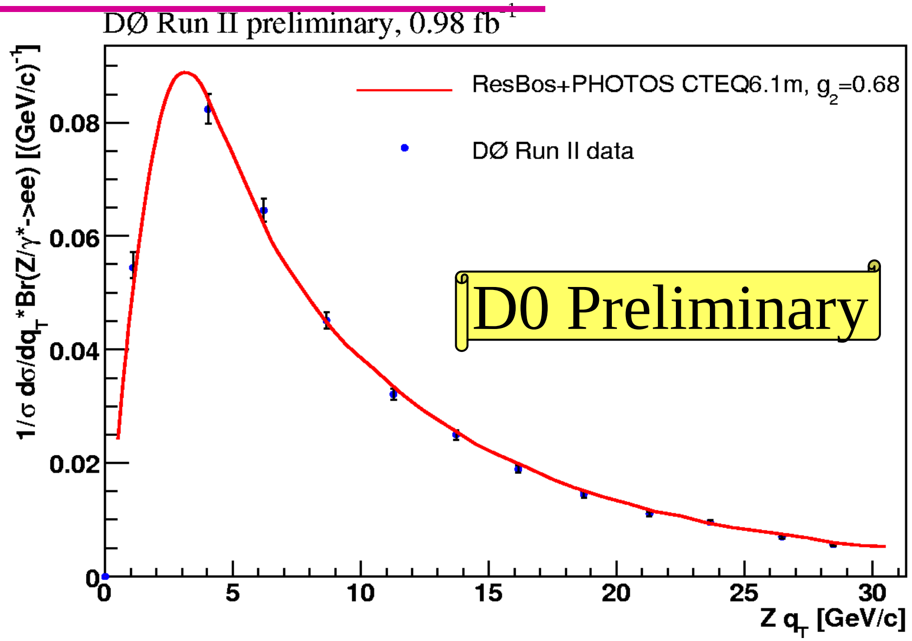
Soft Physics Tunes: q_T Resummation

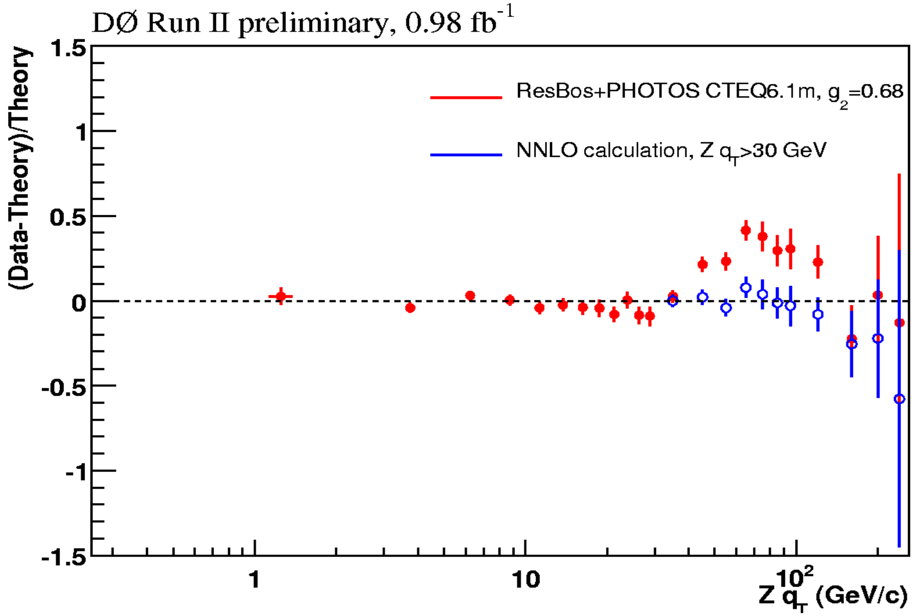
$p_T(V)$ from Analytical Resum. vs D0 Run II

- Data:

$$\int \mathcal{L}dt = 0.98\ fb^{-1}$$

  - $\gamma^*/Z(\rightarrow ee)+X$
  - $40 < M_{ee} < 200$ GeV, $|y_{ee}|<3$
  - Analysis: $0 < q_T < 260$ GeV
- Theory:
  - CSS formalism
  - Tools:
    - **ResBos** (NLL resum. @ low q_T, NLO QCD @ high q_T)
    - **Photos** (QED radiations)
- Conclusions:
  - Low q_T: good agreement
  - High q_T: bad agreement wrt NLO! good agreement wrt NNLO!





Matrix Elements: NLO Normalization

MCFM

- Authors: J.M. Campbell, R.K. Ellis
- Programming Language: Fortran 77
- Set of hard-coded LO & NLO ME (SM, Higgs)
- Output: total and differential cross sections @ LO and NLO
- Parton level cuts possible
- N_{LO}(FS partons)<4; N_{NLO}(FS partons)<3
- Interface to LHAPDF
- Large nber of SM processes
- NLO ME have massles b and c quarks, LO can account for these masses

- Beyond NLO: Note that
  - σ_{NNLO} (p+p/pbar→t+tbar) are available

    ref$_1$: N. Kidonakis and R. Vogt, Phys.Rev.D68 (2003) 114104

    ref$_2$: M. Cacciari et al., JHEP 0404 (2004) 068
  - σ_{NNLO} (p+p/pbar→W/Z) are available

    ref$_1$: R. Hamberg, W.L. van Neerven, T. Matsuura, Nucl.Phys.B359 (1991) 343; Err.-Ibid. B644 (2002) 403

    ref$_2$: K. Melnikov and F. Petriello Phys. Rev. D74 (2006) 114017

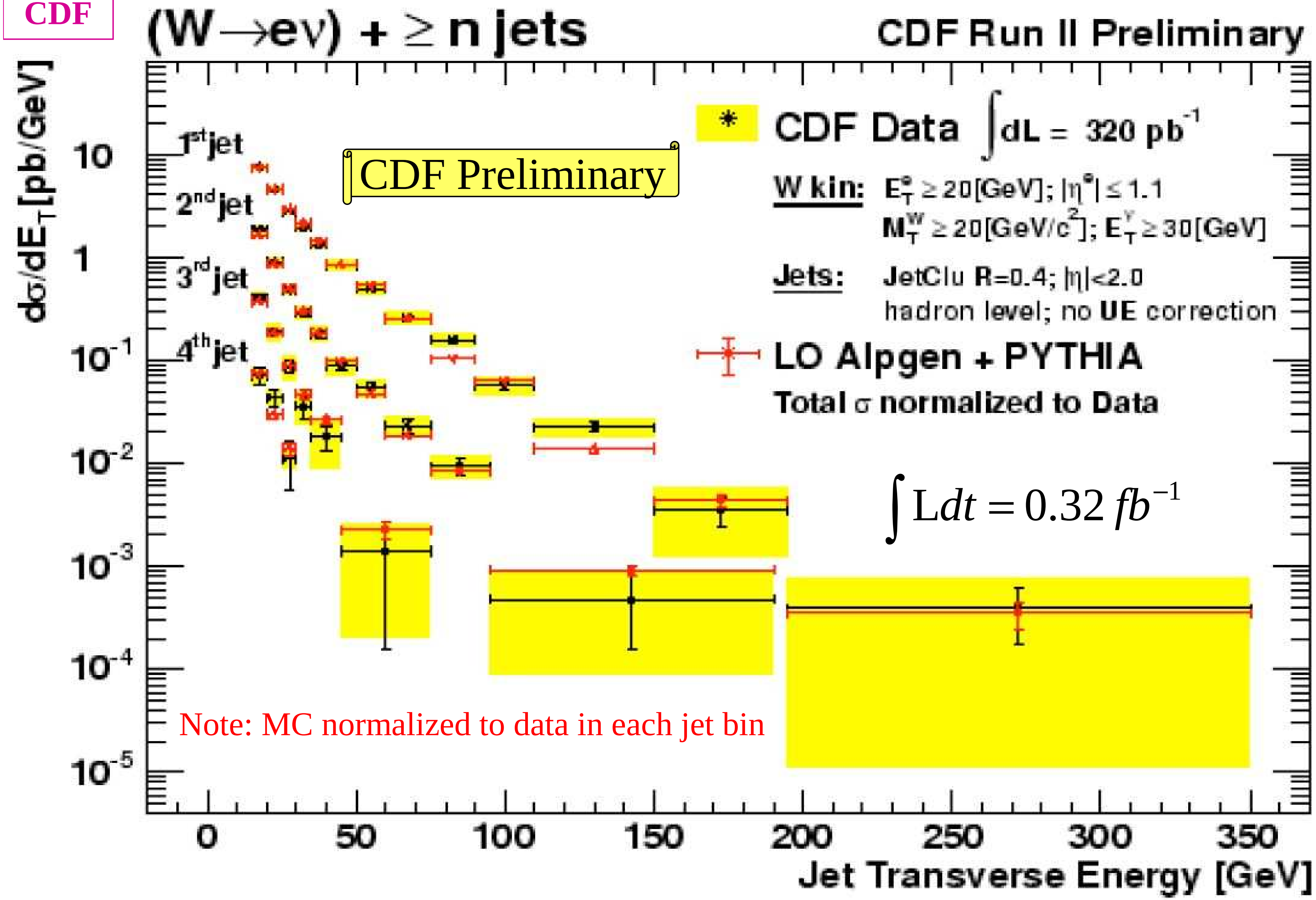
Matrix Elements: LO Matched to Parton Shower

Alpgen v2

- Authors: ML. Mangano et al.
- Programming Language: Fortran 77 (90)
- Set of hard-coded LO ME + Alpha algorithm (SM, Higgs, user-supplied NP)
- Parton Shower: interface to Pythia or Herwig
- MLM Matching between ME-PS (provided)
- LO Normalization, LL Shapes
- Recent CTEQ & MRST PDF files available
- Large nber of FS partons (and γ)
- Special decays:
  - Taus: Tauola interface to Pythia & Herwig
  - B/C-Hadrons: EvtGen interface to Pythia & Herwig

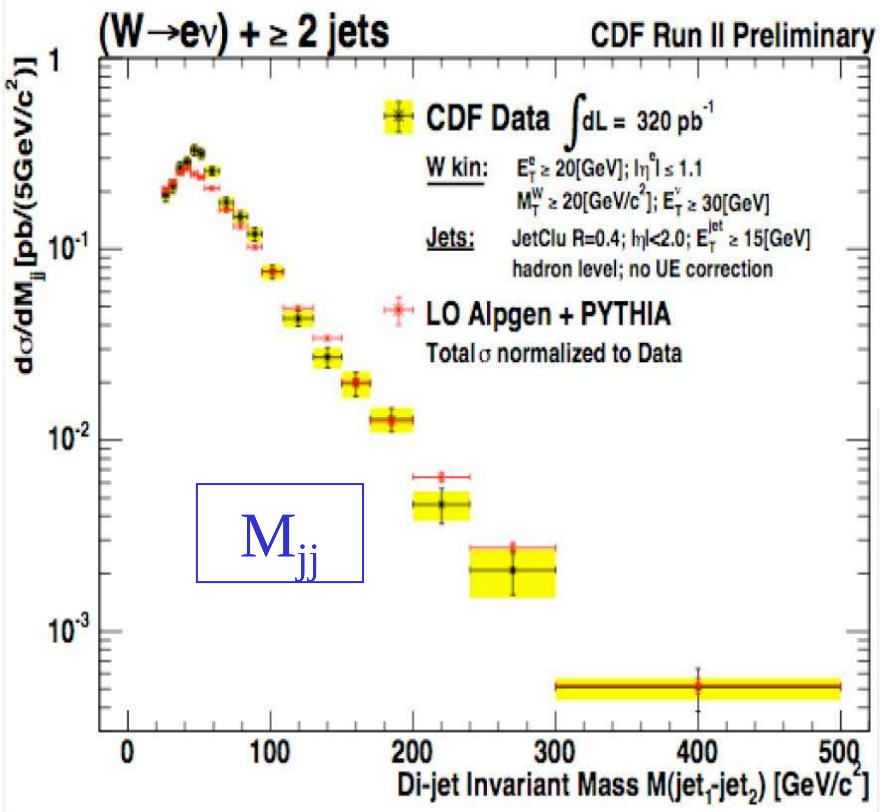
W(→eν)+jets @ CDF Run II

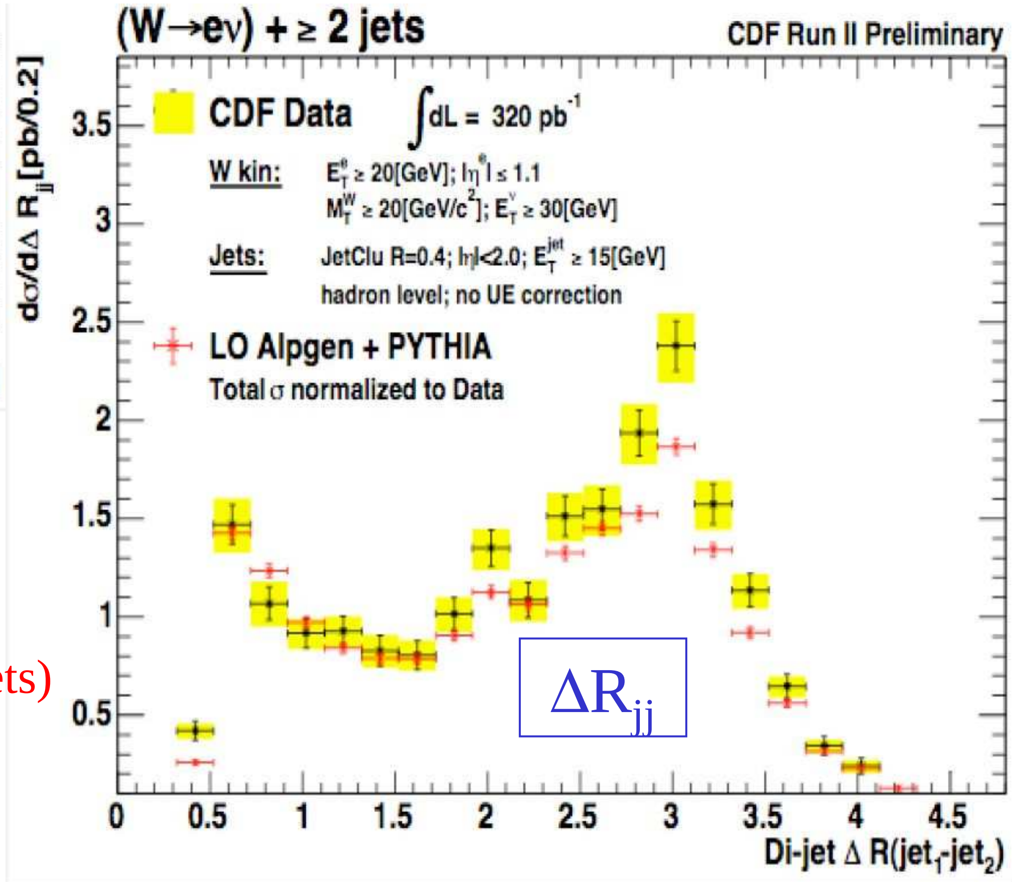
CDF



$$\int Ldt = 0.32\ fb^{-1}$$

Note: MC normalized to data in each jet bin





Note:
MC normalized to the measured σ_{incl}(W+2jets)

Matrix Elements: LO Matched to Parton Shower

Sherpa

- Authors: F. Krauss et al.
- Programming Language: C++
- « Generator » of LO ME (SM, Higgs, SUSY, ED) → AMEGIC++
- Parton Shower LUND string → APACIC++
- CKKW Matching between ME-PS
- LO Normalization, LL Shapes
- Interface to LHAPDF v3

  A bit of add’l overhead at startup, but very powerful & self-contained package

  Limitation in the nber of FS partons???

  Reproduces MC@NLO shapes in many cases

  …

  NP: Can generate consistently signal and background

- Special decay module: → HADRONS++
  - Taus: self-contained, spin-corr. uses helicity amplitudes

Matrix Elements: LO Matched to Parton Shower

$\gamma^*/Z(\rightarrow ee)$+jets @ D0 Run II

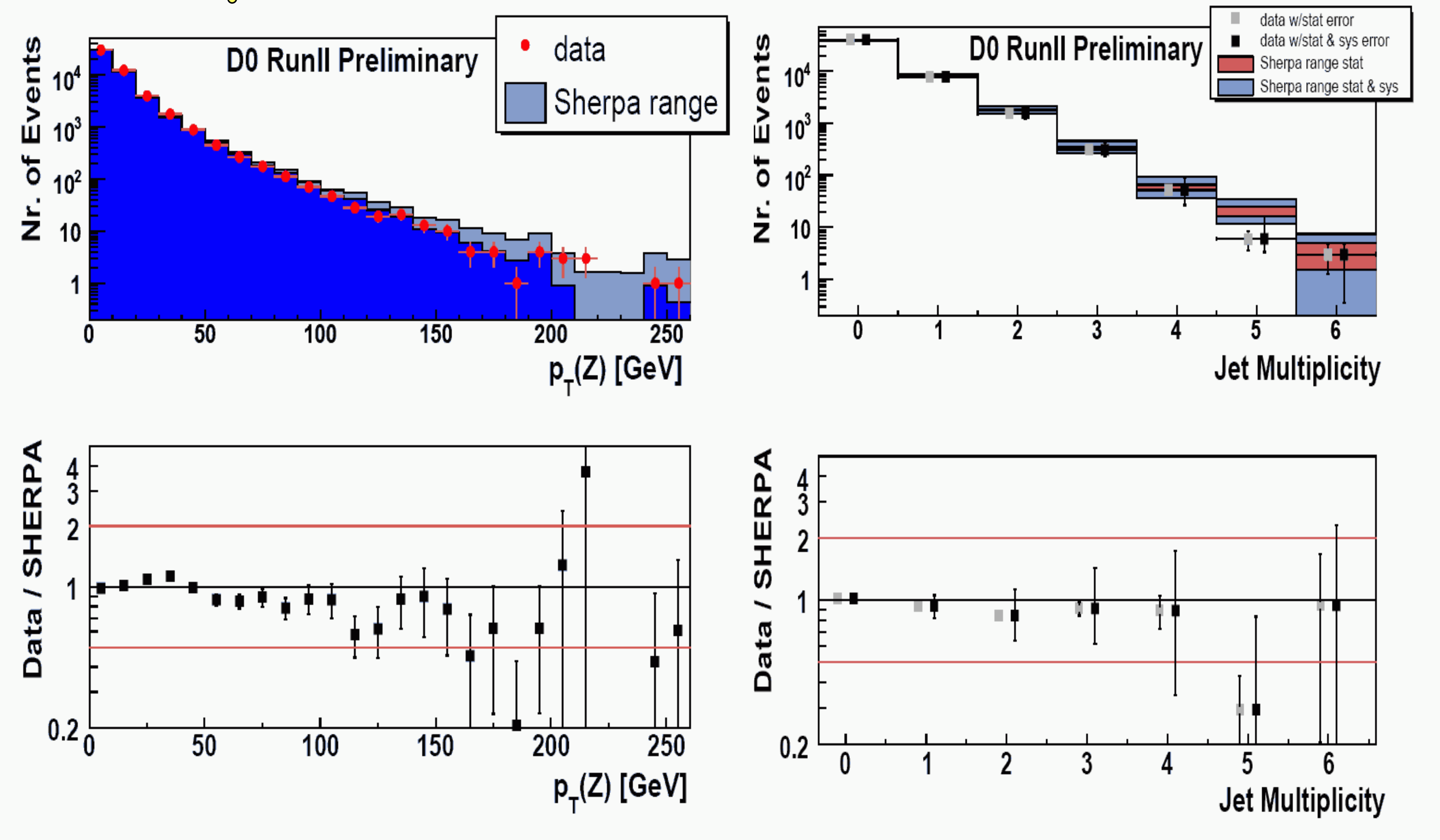
$$\int \mathcal{L}dt = 0.95\, fb^{-1}$$

- Trigger: e and di-e
- 2 OS e, $p_T(e) > 25$ GeV, $|\eta(e)| < 1.1$ and $|\eta(e)| < 2.5$,
- e-likelihood, E/p cut,…
- Use evts within $70 < M_{ee} < 100$ GeV
- Jets: midpoint cone w/ split-merge
  - $\Delta R = 0.5$
  -
- MC: Sherpa v1.0.6
  - PDF: CTEQ6L1
  - ME: Z+0j, Z+1j, Z+2j, Z+3j * CKKW Matching

Matrix Elements: LO Matched to Parton Shower

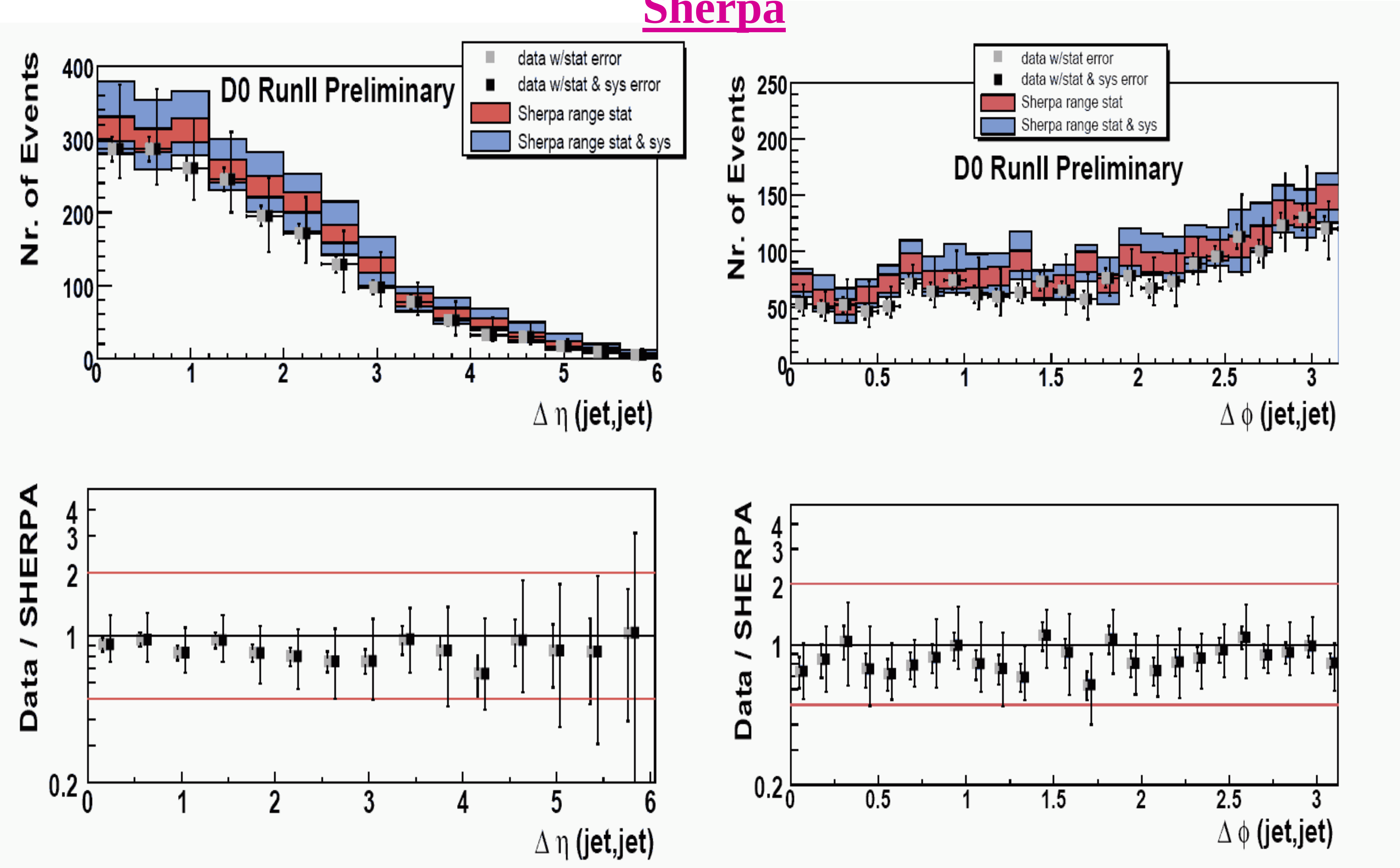
D0 Preliminary

Sherpa



Matrix Elements:
LO Matched to Parton Shower

Sherpa

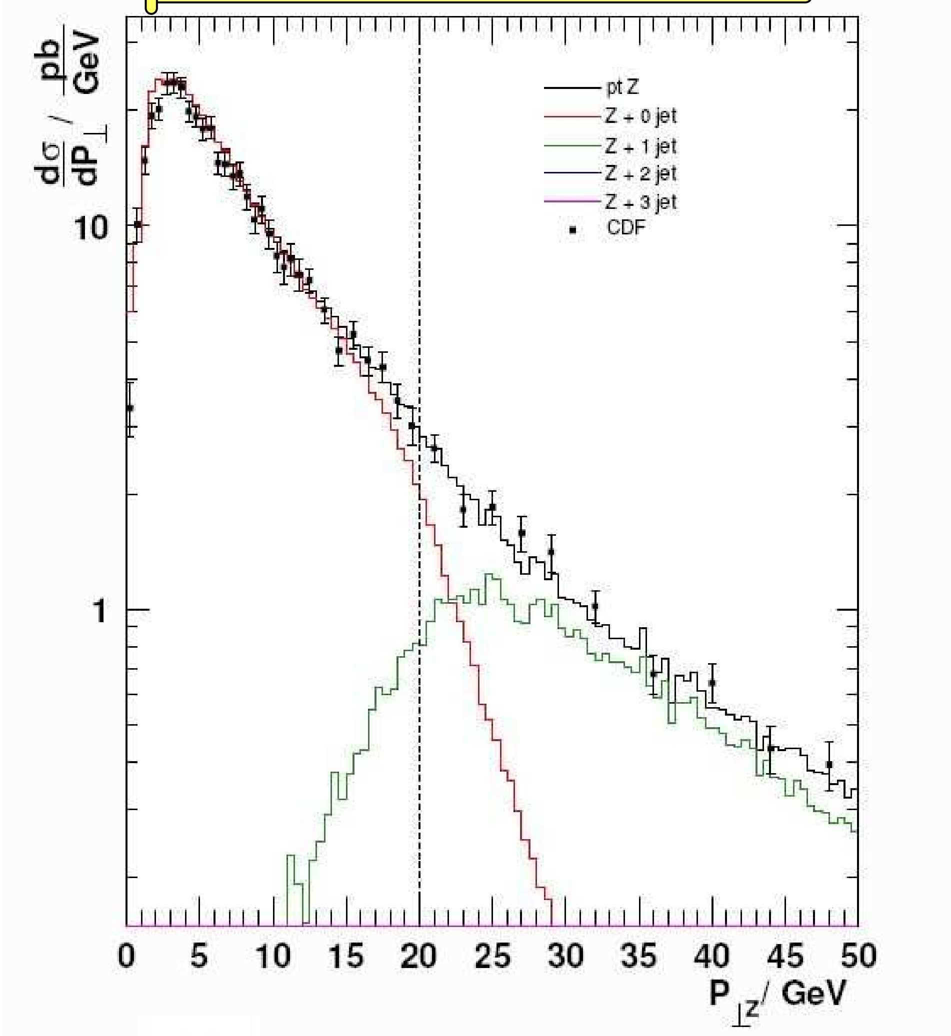


CDF & D0 Run I

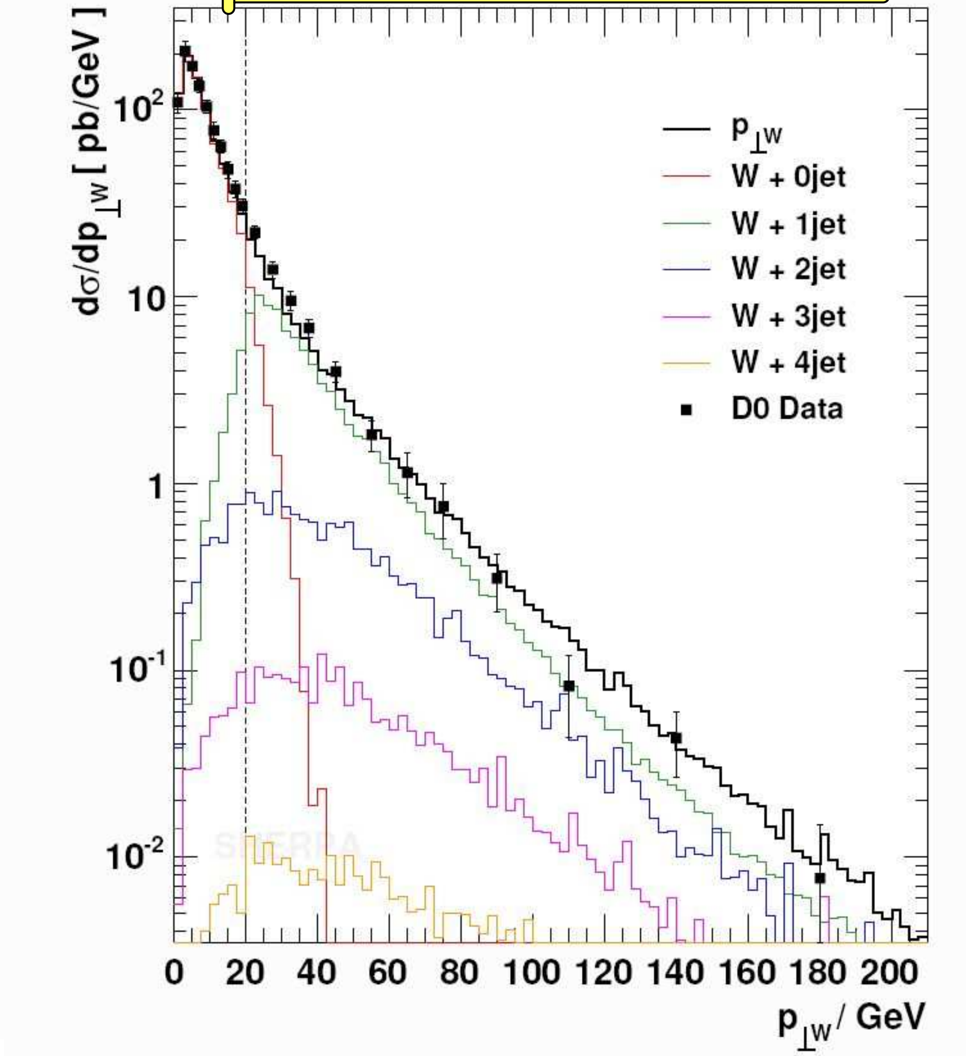
Sherpa x K-factor

S. Höche

Phys. Rev. Lett. 84 (2000) 845-850



Phys. Lett. B513 (2001) 292-300



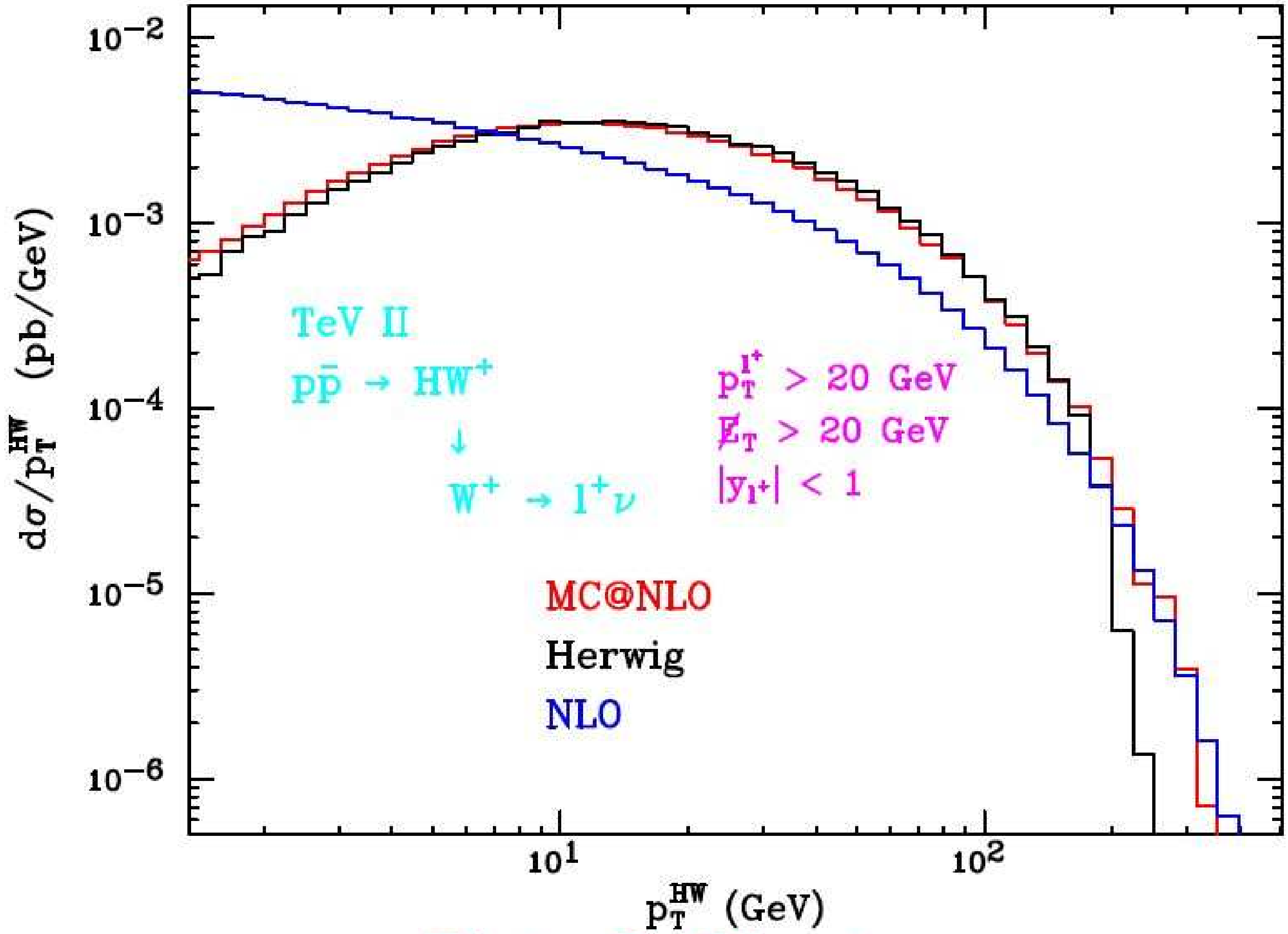
Matrix Elements: LO Matched to Parton Shower

MC@NLO

- Authors: S. Frixione, B.R. Webber
- Programming Language: Fortran 77
- Set of hard-coded NLO ME (SM, Higgs)
- Parton Shower: Herwig (cluster model)
- Special Matching between ME and Herwig PS
- Small nber of partons in FS (do not use for multijet topologies)
- NLO Normalization, NLL Shapes (up-to 1st emission, rest is PS)
- Reproduces PS in soft/collinear regions and ME in hard/wide angle emissions

MC@NLO

S. Frixione



Plot: C. Oleari

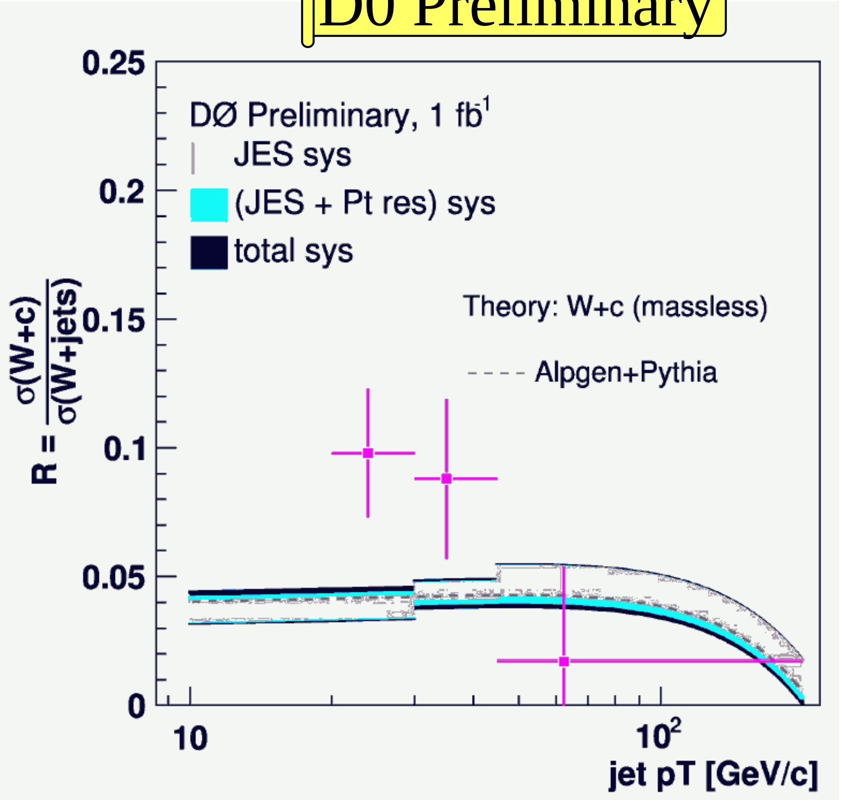
V+HF-jets

W+c @ D0 Run II

$$\int \mathcal{L} dt = 1\, fb^{-1}$$

- Events Sel.:
  - $p_T(e/\mu) > 20$ GeV, $|\eta(e/\mu)| < 2.5$
  - $mE_T > 20$ GeV
  - c-jets tagging: (non isol.) soft μ tag
  - soft μ OS wrt $\ell^{\pm} = e^{\pm} / \mu^{\pm}$ from $W^{\mp}$ decay
  - Jets:
    - $\Delta R = 0.5$
    - $|\eta| < 2.5$
- Extract c-jet fraction using p_T(jets) > 20 GeV
- Measured for the 1st time @ hadron collider

D0 Preliminary



$$\frac{\sigma[W^{\pm}(\to \ell^{\pm}\nu) + c + X]}{\sigma[W^{\pm}(\to \ell^{\pm}\nu) + jets]} = 0.071 \pm 0.017$$

- Conclusion: in agreement wrt LO QCD $\qquad R = 0.040 \pm 0.003(PDF)$

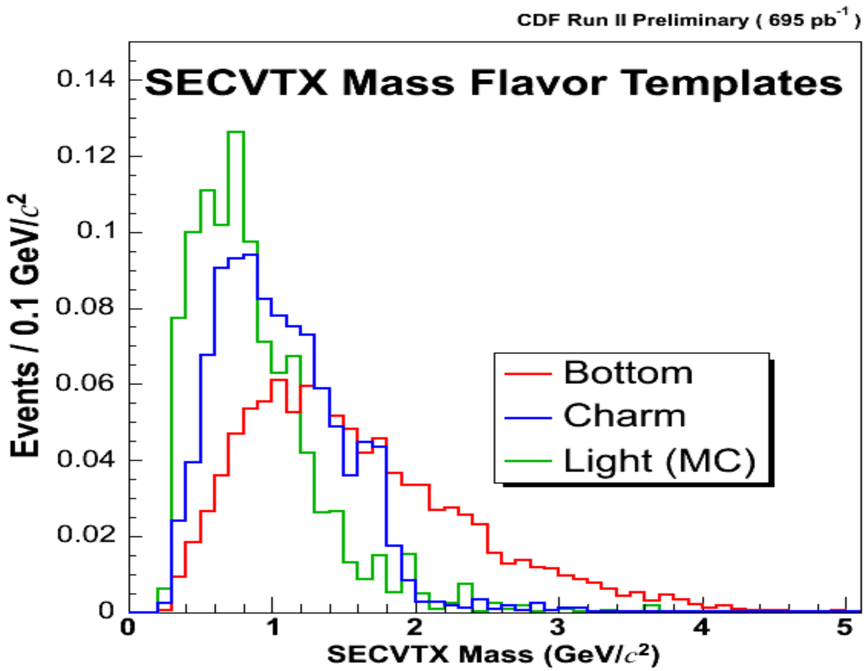
(w/ s-quark PDF evolved from fixed target expt to Tevatron Q^2)

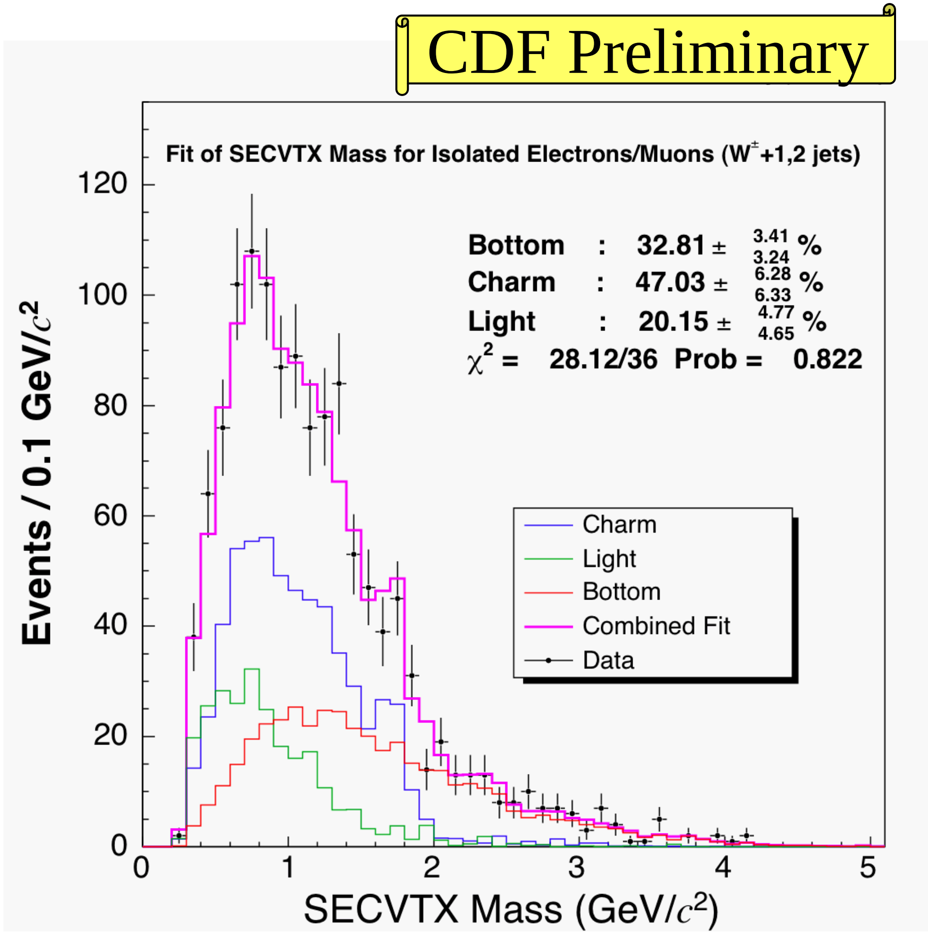
- Prospect: w/ more $\mathcal{L}_{int}$ will constrain s-quark PDF

V+HF-jets

W+bb @ CDF Run II

$$\int \mathcal{L}dt = 0.7\ fb^{-1}$$





- Measure: σ(W+bb) = 0.90±0.32 pb (E_T(j)>20 GeV, |η|<2.0)
- Theory: σ(W+bb) = 0.74±0.18 pb (ALPGEN: LO QCD)
- NB: no anomalies « à la super b-jets » found in CDF & D0 Run II

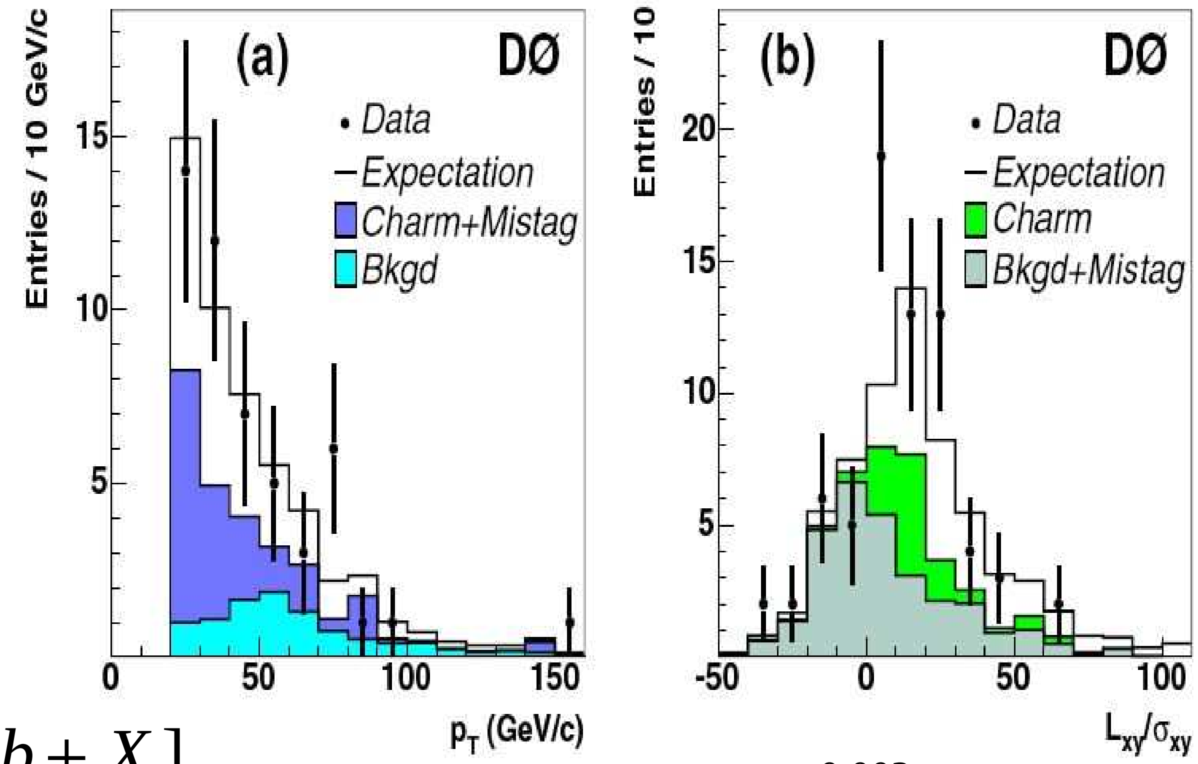
V+HF-jets

Z+b @ D0 Run II

$$\int \mathcal{L} dt = 0.18\, fb^{-1}$$

Phys. Rev. Lett. 94, 161801 (2005)

- Events Sel.:
  - pT(e/μ)> 20 GeV
  - $80 < M_{ee} < 100$ GeV
  - $65 < M_{\mu\mu} < 115$ GeV
  - Jets:
    - ΔR=0.5
    - |η|<2.5
- Extract b-jet fraction using p_T(jets) > 20 GeV
- First measurement of this kind (at the time)



$$R = \frac{\sigma[Z(\to \ell^+\ell^-) + b + X]}{\sigma[Z(\to \ell^+\ell^-) + jets]} = 0.021 \pm 0.004(stat)^{+0.002}_{-0.003}(syst)$$

- Conclusion: in agreement wrt NLO QCD using MCFM: $R = 0.018 \pm 0.004$

- Prospect: window to check b-quark PDF (not enough stat. to constrain)

V+HF-jets

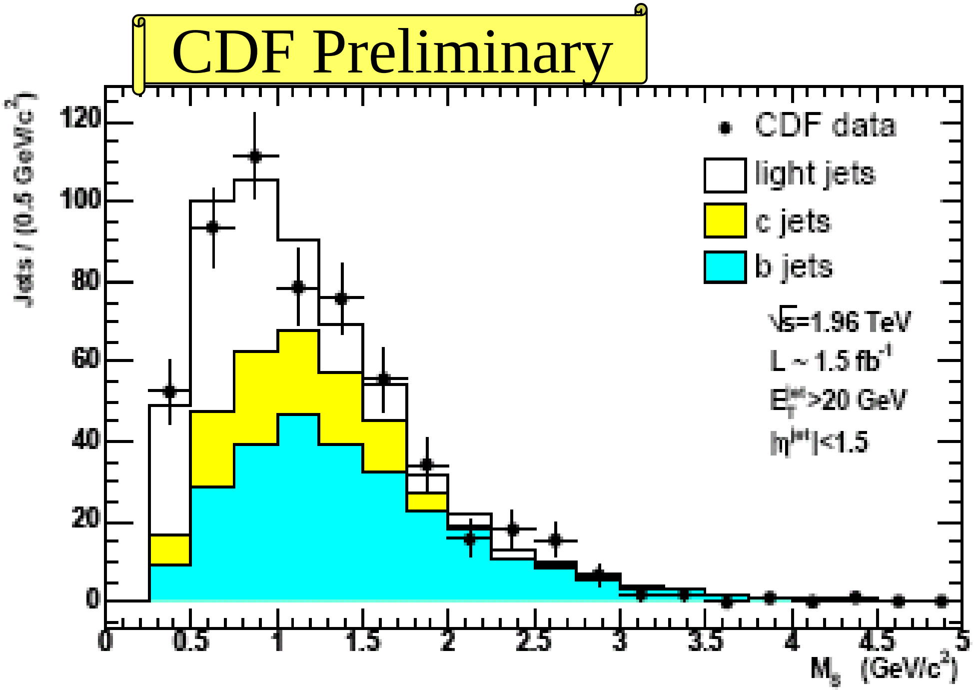
Z+b @ CDF Run II

$$\int \mathcal{L}dt = 1.5\, fb^{-1}$$

Sec. Vtx mass fit in events with at least 1 tagged jet

UE and hadronization corrections:

- derived using Pythia (Tune A)
- sytematics=|Pythia-Herwig|



	CDF Run II Preliminary Data	PYTHIA	MCFM NLO	MCFM NLO +ue +had
$\sigma(Z^0 + b\,\text{jet})$	$0.94 \pm 0.15 \pm 0.15$ pb	0.84	0.51	0.56
$\sigma(Z^0 + b\,\text{jet})/\sigma(Z^0)$	$0.00369 \pm 0.00057 \pm 0.00055$	0.0035	0.0021	0.0023
$\sigma(Z^0 + b\,\text{jet})/\sigma(Z^0 + \text{jet})$	$0.0235 \pm 0.0036 \pm 0.0045$	0.0218	0.0188	0.0177

- Conclusion: σ(Z+b) is 2σ away from MCFM (NLO QCD)

V+HF-jets

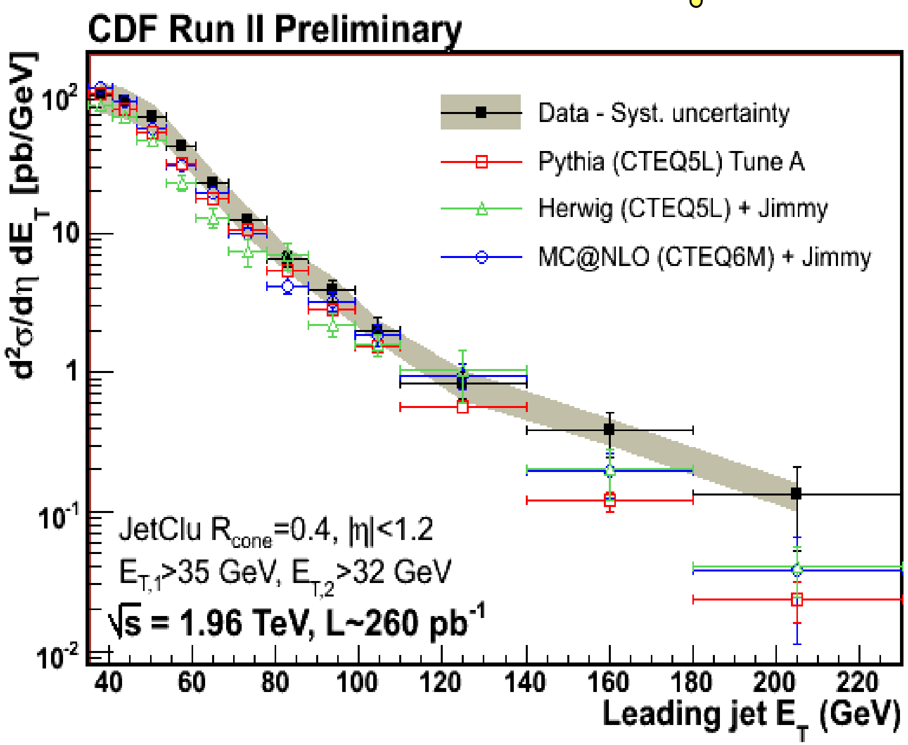
Di-b-jets @ CDF Run II

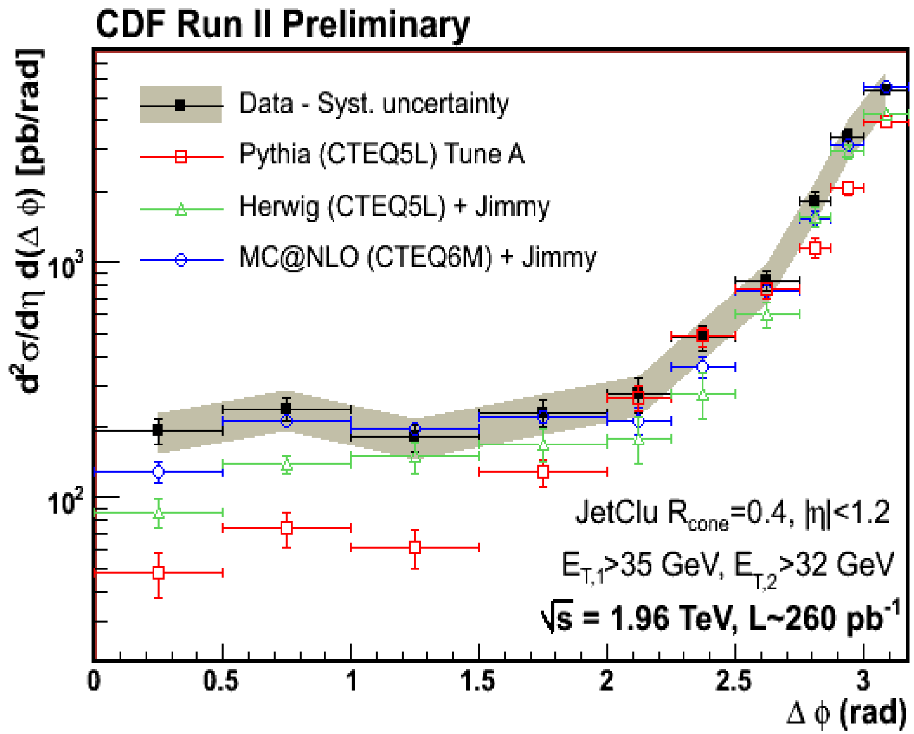
$$\int \mathcal{L}dt = 0.26\ fb^{-1}$$

Note that $\Delta\phi(b_1,b_2)$ is dominated by:

- the flavor excitation and gluon splitting sub-processes at small $\Delta\phi$
- the flavor creation sub-process at large $\Delta\phi$

CDF Preliminary





Conclusions

- Soft Physics Tunes:
  - Possibility to tune Soft Physics w/ PS generators
    - UE and Min. Bias collision model => good starting point for the LHC but will have to be re-done

    - Tune $p_T(V)$ using (artificially) large intrinsic k_T , OR
    - Use analytical q_T resummation to predict $p_T(V)$, then reweight using: [MC truth $p_T(V)$] / [Resummed $p_T(V)$] , OR
    - Measure $p_T(V)$ in data, then reweight

- Multijet Topologies:
  - Tools:
    - Alpgen+PS * MLM Matching
    - Sherpa * CKKW Matching
    - Also CompHep, Madgraph,… but no public matching code
  - Results:
    - Good agreement in shapes wrt to Tevatron Run II data, provided NLO norm.

Conclusions

- V+Heavy Flavor:
  - Measure V+HF / V+jets (many systematics cancel in these ratios)
  - Good agreement* wrt NLO QCD

Prospects

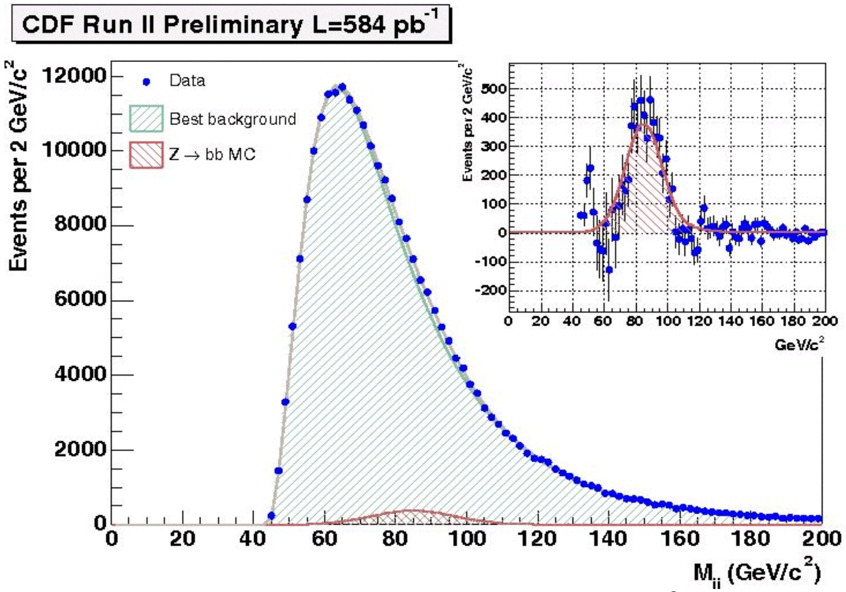
A Specific b-jet Energy Scale

- Will (slightly) improve both central values and resolutions

- In place at CDF:

Signal: Z→bb $\int \mathcal{L}dt = 0.58\ fb^{-1}$

b-jet SF=0.974+/-0.020



CDF Preliminary

- Only partly available at D0:

Correct only for the calorimeter response difference wrt LF-jet: O(+5 %) relative

Signal: γ+b

D0 Preliminary

Additional gains:

- Stat: b-tagging @ trigger LVL at D0
- Energy Flow (or simply « TrackCal » jets at D0)

BACK-UP

Use LO α_s with Λ = 192 MeV!

NLO Structure Function!

Parameter	Tune DW	Tune D6	Tune QW	Tune QK
PDF	CTEQ5L	CTEQ6L	CTEQ6.1	CTEQ6.1
MSTP(2)	1	1	1	1
MSTP(33)	0	0	0	1
PARP(31)	1.0	1.0	1.0	1.8
MSTP(81)	1	1	1	1
MSTP(82)	4	4	4	4
PARP(82)	1.9 GeV	1.8 GeV	1.1 GeV	1.9 GeV
PARP(83)	0.5	0.5	0.5	0.5
PARP(84)	0.4	0.4	0.4	0.4
PARP(85)	1.0	1.0	1.0	1.0
PARP(86)	1.0	1.0	1.0	1.0
PARP(89)	1.8 TeV	1.8 TeV	1.8 TeV	1.8 TeV
PARP(90)	0.25	0.25	0.25	0.25
PARP(62)	1.25	1.25	1.25	1.25
PARP(64)	0.2	0.2	0.2	0.2
PARP(67)	2.5	2.5	2.5	2.5
MSTP(91)	1	1	1	1
PARP(91)	2.1	2.1	2.1	2.1
PARP(93)	15.0	15.0	15.0	15.0

UE Parameters

K-factor (T. Sjostrand)

Tune A energy dependence!

ISR Parameter

Intrinsic KT

Parameter	Tune DWT	ATLAS	Tune D6T	Tune QWT	Tune QKT
PDF	CTEQ5L	CTEQ5L	CTEQ6L	CTEQ6.1	CTEQ6.1
MSTP(2)	1	1	1	1	1
MSTP(33)	0	0	1	1	1
PARP(31)	1.0	1.0	1.0	1.0	1.8
MSTP(81)	1	1	1	1	1
MSTP(82)	4	4	4	4	4
PARP(82)	1.9409 GeV	1.8 GeV	1.8387 GeV	1.1237 GeV	1.9409 GeV
PARP(83)	0.5	0.5	0.5	0.5	0.5
PARP(84)	0.4	0.5	0.4	0.4	0.4
PARP(85)	1.0	0.33	1.0	1.0	1.0
PARP(86)	1.0	0.66	1.0	1.0	1.0
PARP(89)	1.96 TeV	1.0 TeV	1.96 TeV	1.96 TeV	1.96 TeV
PARP(90)	0.16	0.16	0.16	0.16	0.16
PARP(62)	1.25	1.0	1.25	1.25	1.25
PARP(64)	0.2	1.0	0.2	0.2	0.2
PARP(67)	2.5	1.0	2.5	2.5	2.5
MSTP(91)	1	1	1	1	1
PARP(91)	2.1	1.0	2.1	2.1	2.1
PARP(93)	15.0	5.0	15.0	15.0	15.0

Use LO α_s with Λ = 192 MeV!

UE Parameters

ISR Parameter

Intrinsic KT

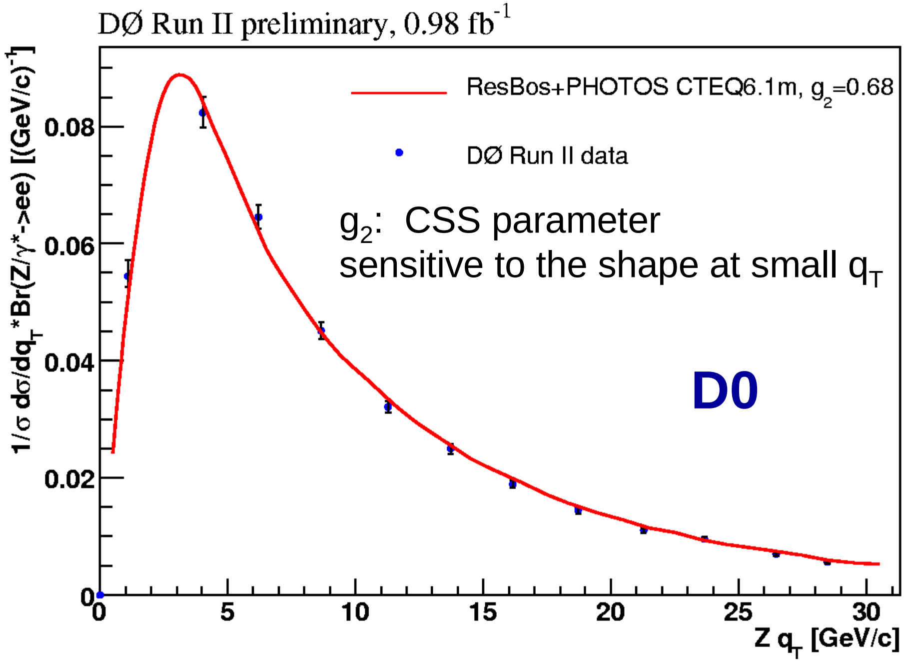
NLO Structure Function!

K-factor (T. Sjostrand)

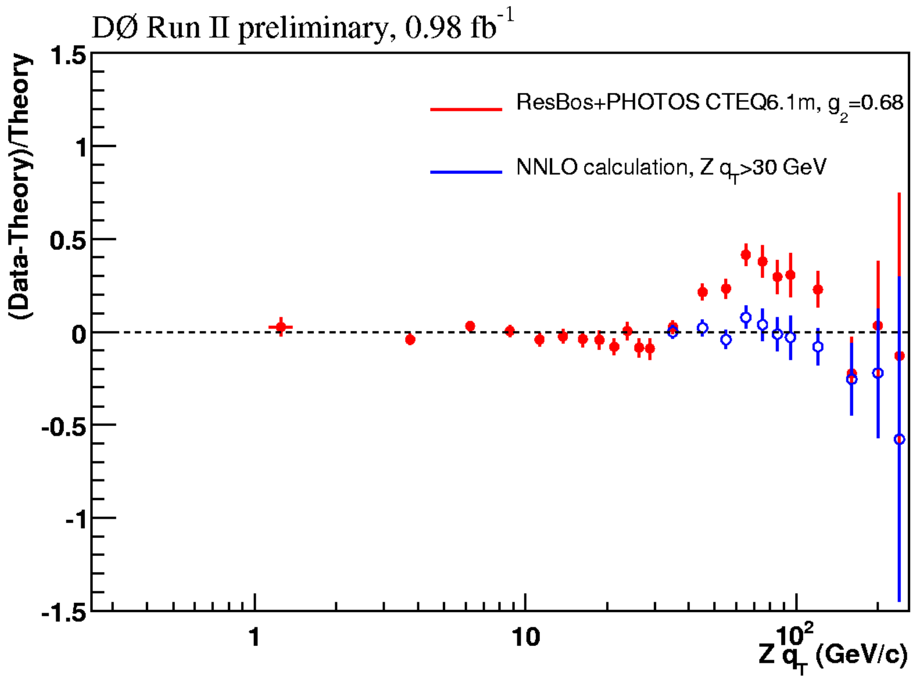
Tune A energy dependence

Soft Physics Tunes: q_T Resummation

$p_T(V)$ from Analytical Resum. vs D0 Run II



$40 < M_{ee} < 200$ GeV
$0 < q_T < 260$ GeV
$|Y| < 3$



In agreement with perturbative QCD augmented by Collins-Soper-Sterman (CSS) resummation at low q_T

J. Collins, D. Soper, G. Sterman, Nucl. Phys. B250 (1985) 199.

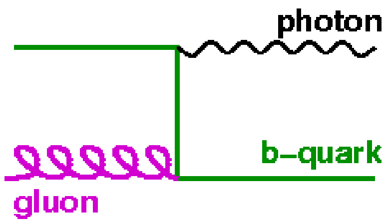
ResBos describes data well up to ~ 30 GeV

F. Landry, R. Bock, P.Nadolsky, C.P. Yuan
Phys. Rev. D 67, 073016 (2003)

NNLO describes better above 30 GeV

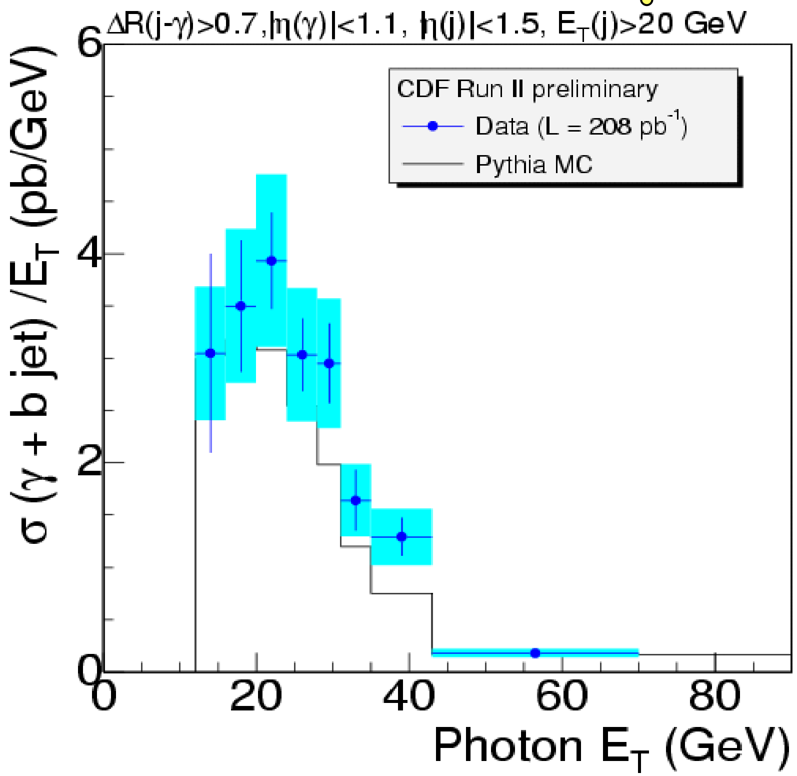
K. Melnikov and F. Petriello Phys. Rev. D74 114017 (2006)

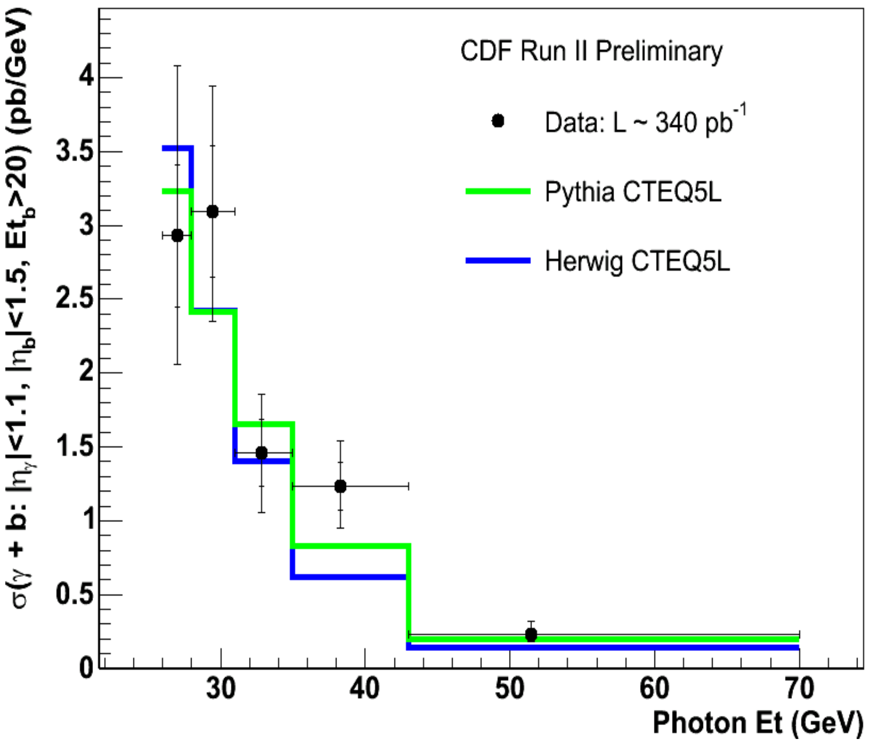
γ+b @ CDF Run II



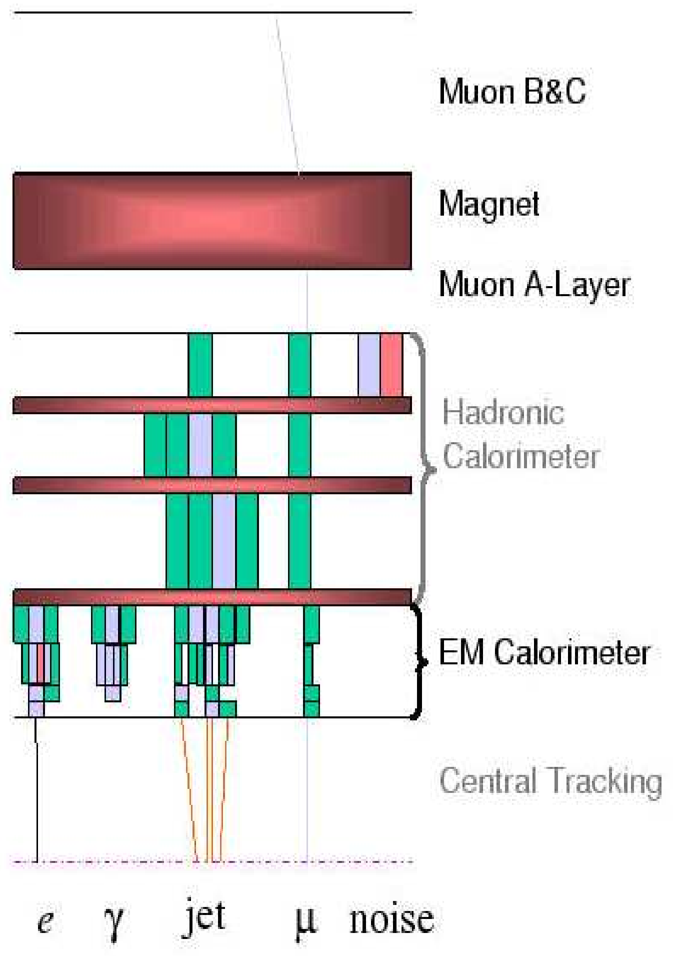
- Probes heavy-quark PDFs
- Experimentally difficult because of large background from π^0 decays

CDF Preliminary





Particle identification



- There are 2 classes of Event Generators:
  1. The « Parton Shower » Generators (aka MC)
  2. The « Matrix Element » Generators (aka FOME)

Basic « How To »

PS

- Start from 2→N (LO) ME, w/ N up to 2/3
- Radiate IS and FS gluons
- Start parton showers from those
  - note that each branching iteratively decreases Q(node i)< Q(hard scatter) … downto Q(node f)~Λ_{QCD}

  => it creates a natural link between the hard scatter and the hadronization scale
- Underlying event (including MPI)
- Decay of unstable particles
- …
- SHAPES: accurate at Leading Log (LL)
- RATES: purely LO normalization is retained

ME

- Start from FIXED ORDER (wrt α_S) ME for 2→N processes, w/ N up to 8 (LO) or 2/3 (NLO)
- Cut off divergent regions of the phase space
- Produce exclusive parton level final states in the rest of the phase space
- …
- SHAPES&RATES: purely the chosen fixed order (LO or NLO)

- There are 2 classes of Event Generators:
  1. The « Parton Shower » (aka MC) Generators
  2. The « Matrix Element » (aka FOME) Generators

PS

Advantages:

- Generate inclusive samples (generate in one shot, directly comparable to data)

Drawbacks:

- Does not account for quantum interferences between compatible transition amplitudes
- Additional jets are mostly produced in special corners of the available phase space (due to the soft and collinear approximation)

Examples:

Pythia, Herwig, Isajet,…
Ariadne (Dipole Showers)

ME

Drawbacks:

- Have to generate exclusive samples (generate in many steps, then mix and merge the samples)

Advantages:

- Explicitely accounts for quantum interferences between compatible transition amplitudes
- Additional jets are correctly produced over the available phase space, but not in some corners (due to singularities of the ME in the soft and collinear regions)

Examples:

Alpgen, Sherpa, Comphep, Vecbos,…
mc@nlo,...

Alpgen & the « MLM » Matching

- Generate a parton level configuration based on LO ME, w/ N_{part} hard partons
- Apply kinematical cuts on those configs: p_{Tpart}^{min} and $\Delta R_{part-part}$
- Perform PS (no showers veto, no Sudakov form factor reweighting)
- Cluster the partons using a jet reco algo: E_{Tj}^{min}, ΔR_j
- Match parton to parton jets:
  - for each ME parton select a parton jet based on $\min(\Delta R_{part-j})$
  - if this $\min(\Delta R_{part-j}) < \Delta R_j$ the parton is matched
  - a parton jet can be matched only to a single ME parton
  - Exclusive matching:
    - Keep the event only if each parton is matched to a jet & $N_{part}=N_{jets}$
  - Inclusive matching:
    - Keep the event only if each parton is matched to a jet & $N_{part}<N_{jets}$
- ickkw option: reweight events by $\alpha_S(k_T^2)/\alpha_S(Q_{HS}^2)$ calculation at each node of the PS
- Public code available in Alpgen v2 (LHA interface to Herwig and Pythia)

. REF:

. Alpgen Doc: M.L. Mangano, http://m.home.cern.ch/m/mlm/www/alpgen/alpdoc.pdf

. hep-ph/0602031, "Matching Parton Showers and Matrix Elements" by S. Hoeche, F. Krauss, N. Lavesson, L. Lönnblad, M.L. Mangano, A. Schaelicke, S. Schumann

Sherpa & the « CKKW » Matching

. Applies to e^+e^- -> jets+X (slightly modified for hadron collisions)
. Try to separate the contributions of ME and PS in the phase space using a k_T cluster paramater y_{ini}
. ME and PS are matched w/:

- modified ME (Sudakov FF and $\alpha_S(k_T^2)/\alpha_S(Q^2)$ reweighting)
- modified showers (vetos to cancel y_{ini} dependance at NLL accuracy)

. Reminder k_T clustering (Durham algo):

$$y_{ij} = \frac{2\times\min(E_i, E_j)^2 \times (1-\cos\theta_{ij})}{Q^2} = \frac{k_T^2}{Q^2}$$

- if $y_{ij} > y_{cut}$ the objects i and j are resolved
- elseif $y_{ij} < y_{cut}$ objects i and j are clustered => $4\text{-}p_{ij} = 4\text{-}p_i + 4\text{-}p_j$

- Note: Process indepenedent procedure!!!

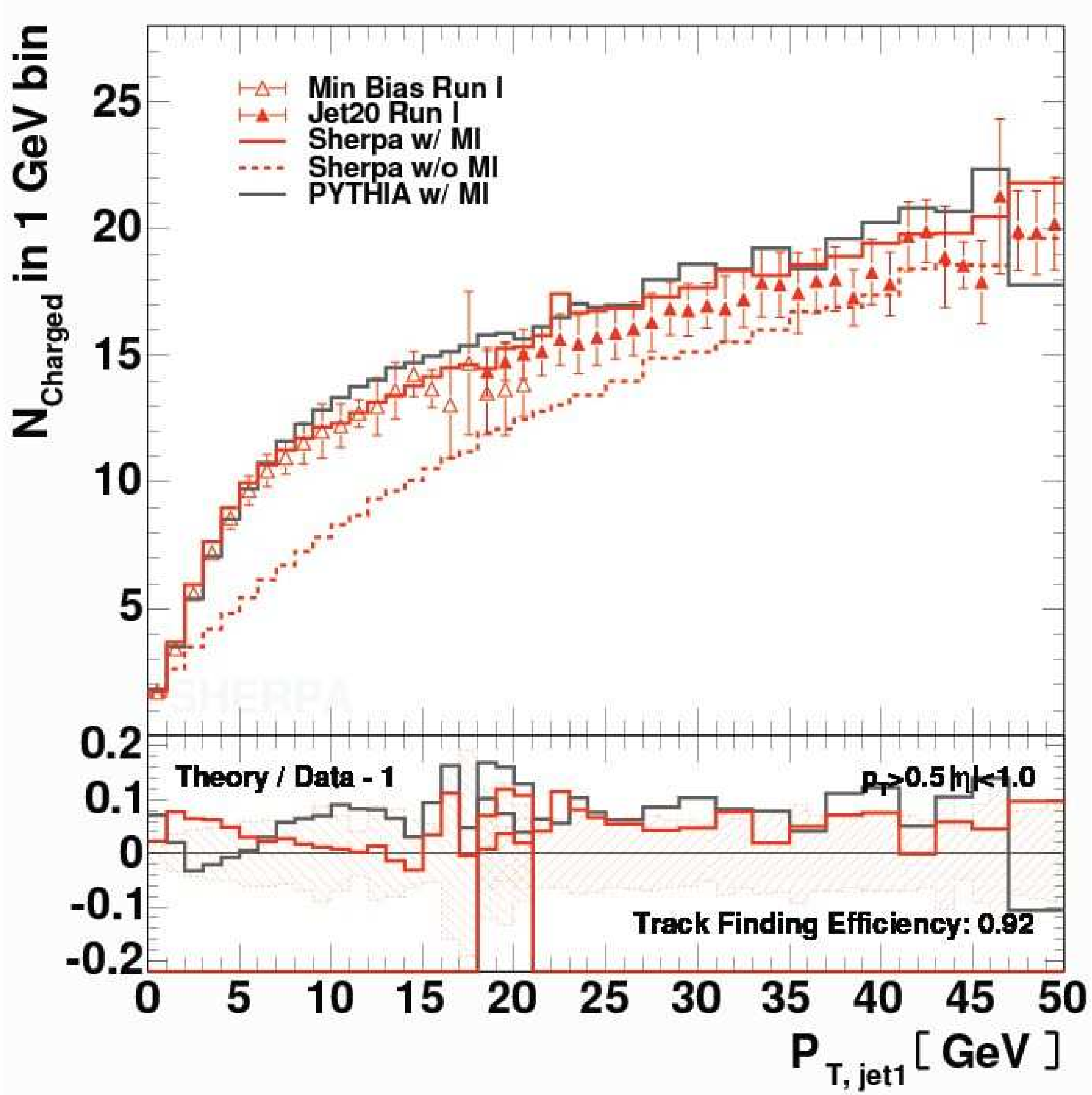
. REF:

S. Catani, F. Krauss, B. Webber, R. Kuhn, JHEP11 (2001) 063
"QDC Matrix elements + parton showers"

CDF Run I

S. Höche

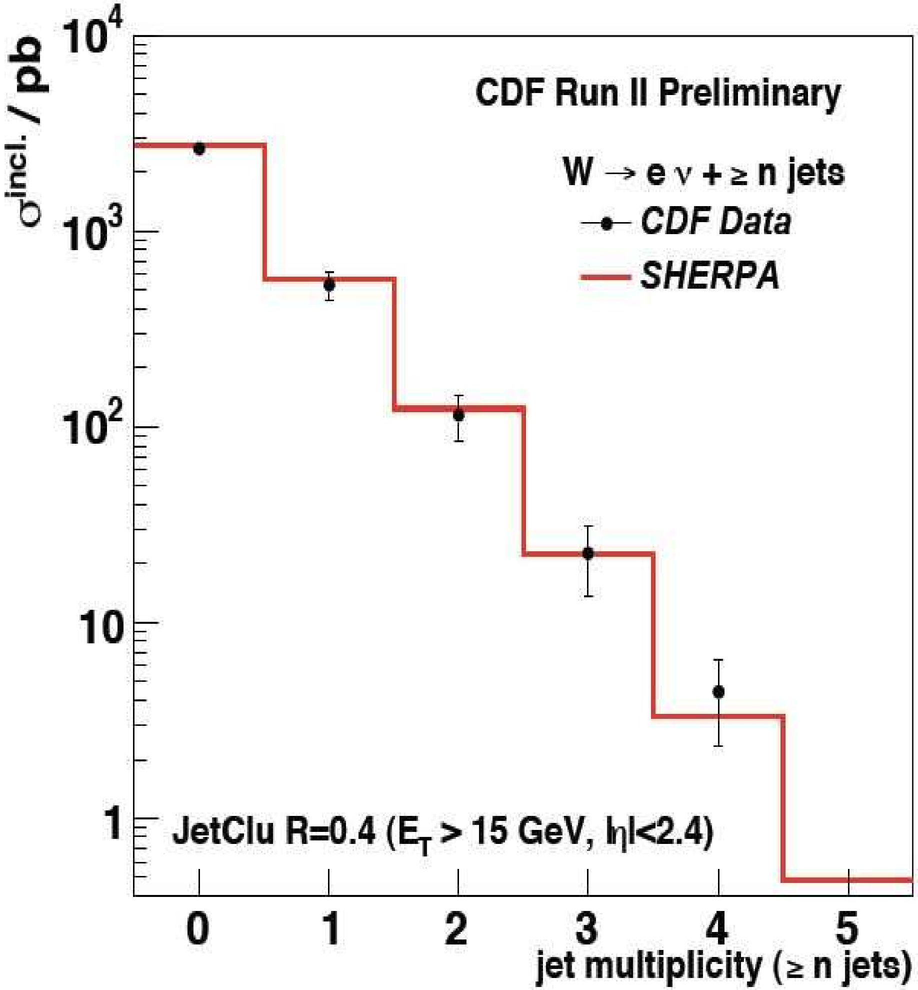
Sherpa Tuned UE

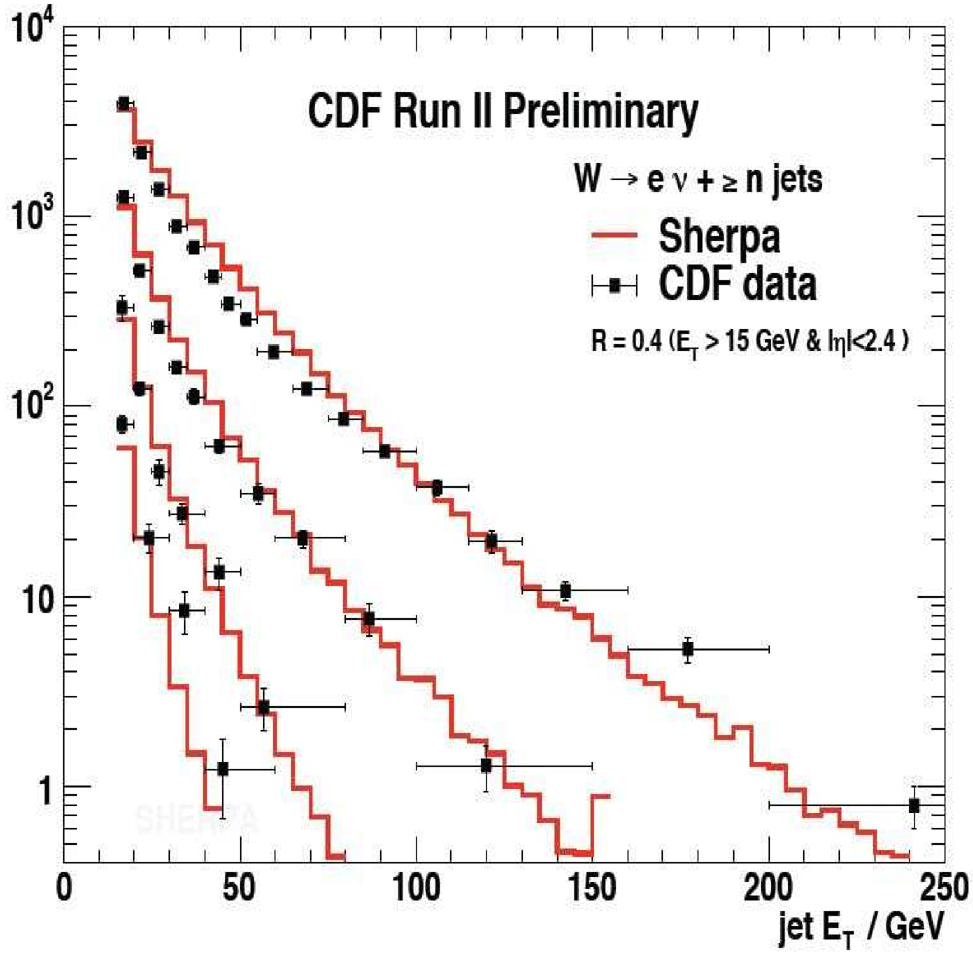


CDF Run II

S. Höche

Sherpa x K-factor





Pythia's Variant of the « CKKW » Matching

- Start w/ parton level configuration based on LO ME
- Feed Pythia w/ this using the full flavor and color flow
- Perform a k_T clustering to determine "nodal values"
- Events are reweighted by $\alpha_S(k_T)/\alpha_S(M_Z)$ factor for each cluster

  e^+e^- -> γ^*/Z ->2p: 0 α_S reweighting,

  3p: 1 α_S reweighting,…

  np: (n-2) α_S reweighting
- The clustering yields a parton shower (PS) history where each line is weighted by a Sudakov form factor
- Primary partons are showered in Pythia from Q_{max}@ nodal value down to $Q=\Lambda_{QCD}$
- In the PS each emission w/ $k_T > k_T$min is vetoed!!!
- To account for unknown higher order contributions (mainly leading logs), the events w/ largest nber of partons is not vetoed

. REF: S. Mrenna and P. Richardson, JHEP05 (2004) 040
"Matching matrix elements and parton showers with HERWIG and PYTHIA"

II. The FOME Generators

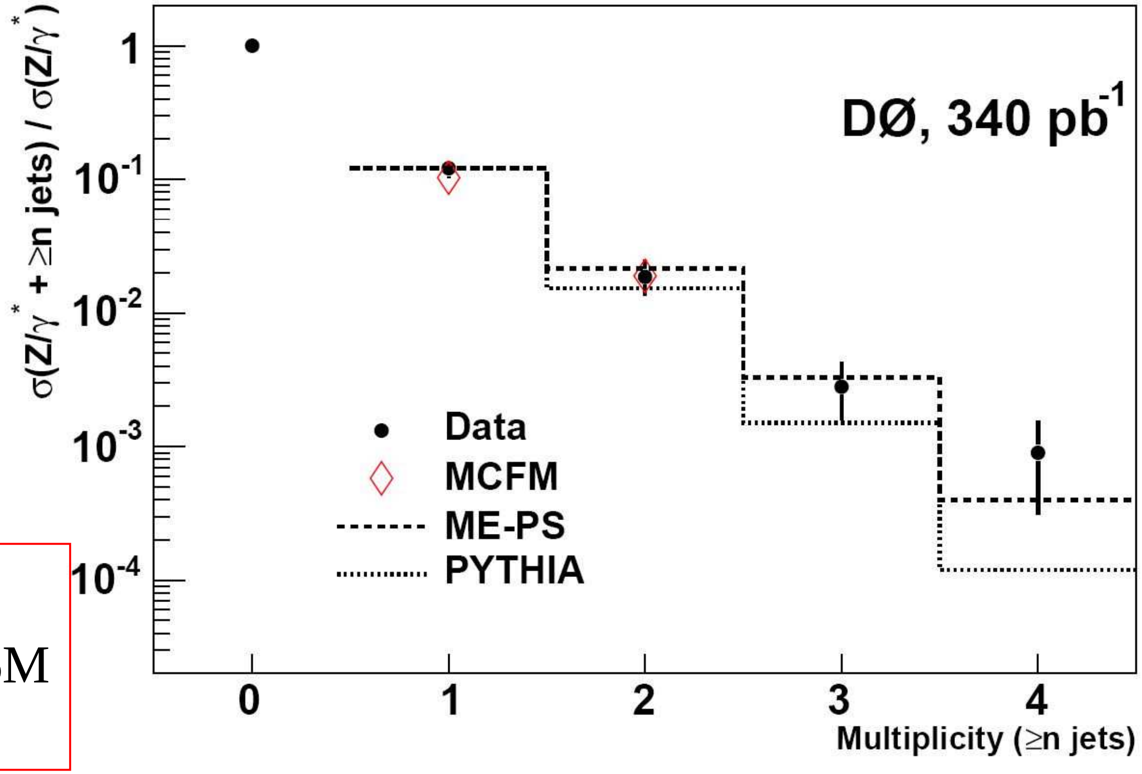
Madgraph+Pythia

- Patriot samples provided by S. Mrenna for CDF and D0 Run II

D0 Pub. 2006

$\gamma^*/Z(+jets) \rightarrow e^{\pm}e^{\mp}$

Madgraph+Pythia:
- ME: Magraph v2
- PS: Pythia v6.2
- ME-PS Matching: modified CKKW (not public)
- PDF: CTEQ6LL
- $Q_F = M_Z$, $Q_R = p_T(jet)$ or $k_T(jet)$



Pythia:
- PDF: CTEQ5L
- $Q_F = Q_R = M_Z$

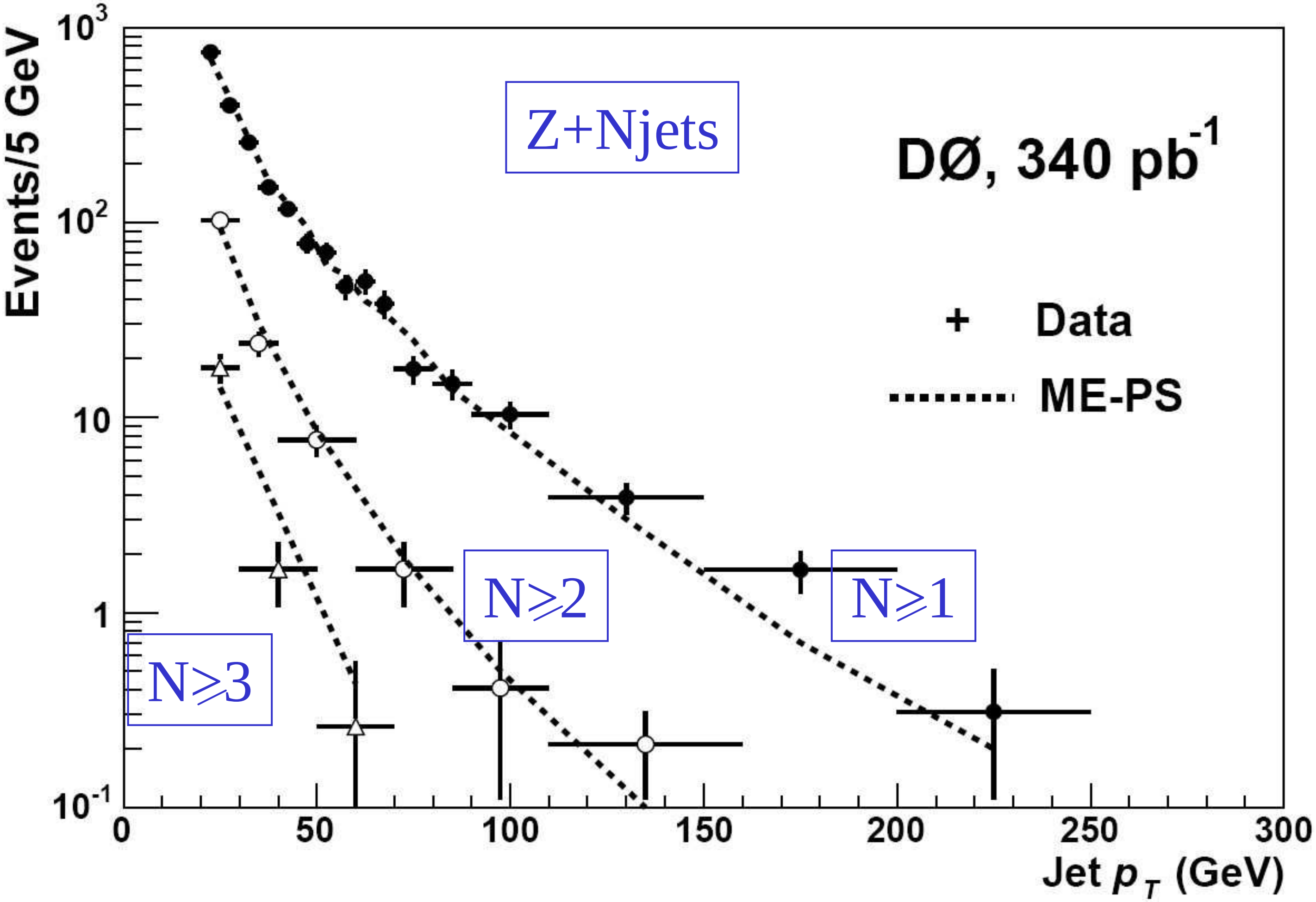
MCFM:
- PDF: CTEQ6M
- $Q_F = Q_R = M_Z$

Event Selection:

- EM ID:
  - 2 isolated e, pT>25 GeV, |η|<1.1
  - at least 1 track match, E/p
  - shower shapes

Event Selection Cont'd:

- Jet ID:
  - Reco: ΔR=0.5
  - trigger confirmed
  - pT>20 GeV, |η|<2.5
  - ΔR(e,j)>0.4



II. The PS Generators

1. Final State Showers (forward evolution)

- Sudakov Form Factor:

$$\Delta_{a\to bc}(t_0,t)=\exp\left(-\int_{t_0}^{t}\frac{dt'}{t'}\int dz\,\frac{\alpha_S(k_T^2)}{2\pi}P_{a\to bc}(z)\right)$$

- Interpretation: 1-$\mathcal{P}$(for a to split into b+c between t_0 and t)

2. Initial State Showers (backward evolution)

- In principle equivalent to FS showers
  - but both end fixed => quite different in practice
- DGLAP Equations:
  - Start at HS Q^2
  - Evolve backwards
  - Weight w/ PDFs at each x and t