Simulating t-tbar signals and backgrounds with Alpgen

Top2007 Workshop
Grenoble, Oct 18-20 2007

Michelangelo L. Mangano
Theoretical Physics Unit
Physics Department
CERN, Geneva

Charge from the organizers only partly covered ...

- Some reminder on the merging procedure
- Some status of the W+jets productions:
    - Wb generation. This is a major backgd to single-top and we would need to understand your plans about it in Alpgen
    - Status for Wc, Wcc, Wbb + jets : How the generation compare to the TeVatron data ? Prospects for the LHC
- Single-top production of Wt and Wt+jets in Alpgen. Are there plans to include H+t(+jets) as well ?
- Top pair production with jets

and some more specific questions:

- Comparison and differences seen between pTW and pTZ TeVatron vs Alpgen
- Maybe the 'usual' question about the top mass definition (pole ...)

Alpgen merging algorithm for multijet final states*

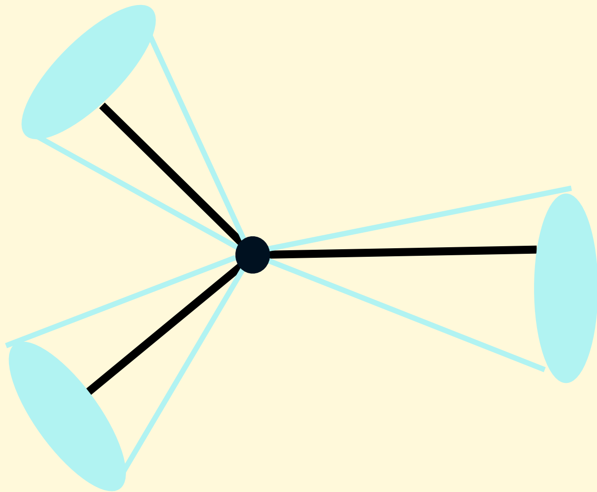
* (a.k.a. MLM's matching)

- **Generate parton-level configurations** for a given hard-parton multiplicity N_{part}, with partons constrained by
  - $p_T > p_{T\,min}$ $\Delta R_{jj} > R_{min}$
- **Perform the jet showering**, using the default Herwig/Pythia algorithms
- Process the showered event (**before hadronization**) with a **cone jet algorithm,** defined by $E_{T\,min}$ and R_{jet}
- **Match partons and jets:**
  - for each hard parton, select the jet with min $\Delta R_{j\text{-}parton}$
  - if $\Delta R_{j\text{-}parton} < R_{jet}$ the parton is "matched"
  - a jet can only be matched to a single parton
  - **if all partons are matched, keep the event, else discard it**
- This prescription defines an **inclusive sample** of $N_{jet}=N_{part}$ **jets**
- Define an **exclusive N-jet** sample by requiring that the number of reconstructed showered jets N_{jet} be equal to N_{part}
- After matching, combine the exclusive event samples to obtain an **inclusive sample containing events with all multiplicities**

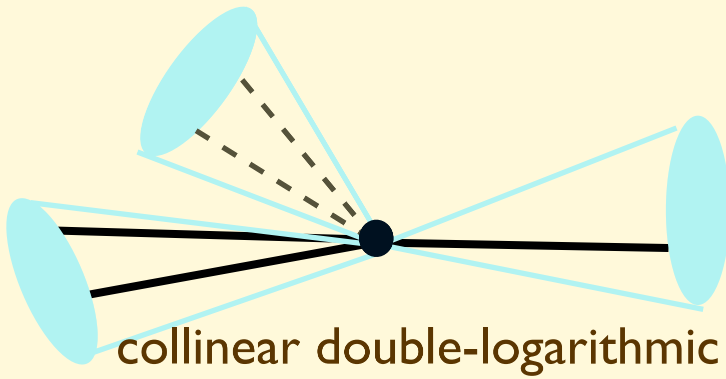
Few examples of matching:

hard parton

parton emitted by the shower



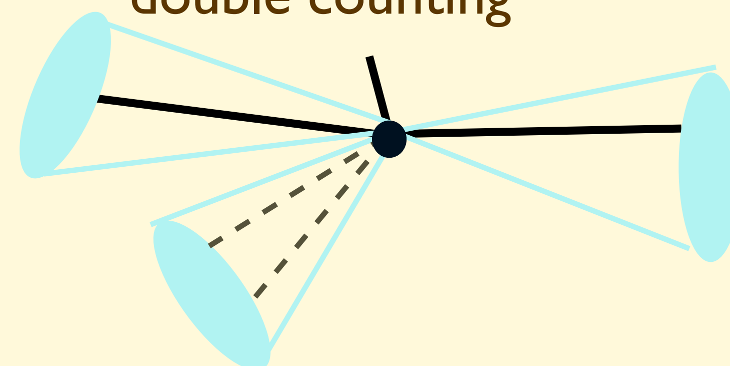
Event matched, $N_{jet}=N_{part}=3$, keep

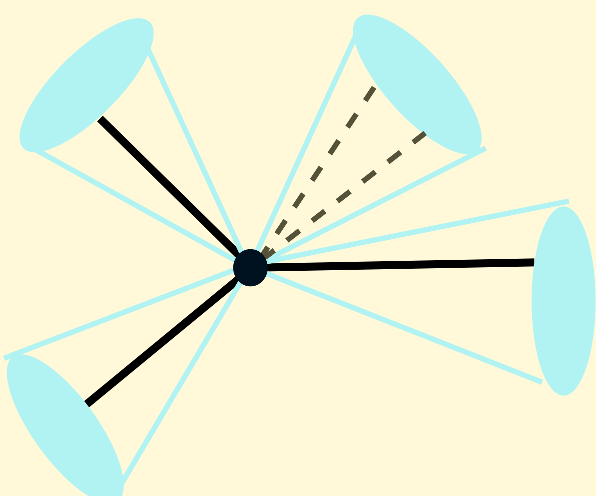


collinear double-logarithmic double counting

NOT matched,
$N_{jet}=N_{part}=3$,
but $N_{match}=2$
Throw away

soft single-logarithmic double counting





Event matched, $N_{jet}>N_{part}$:

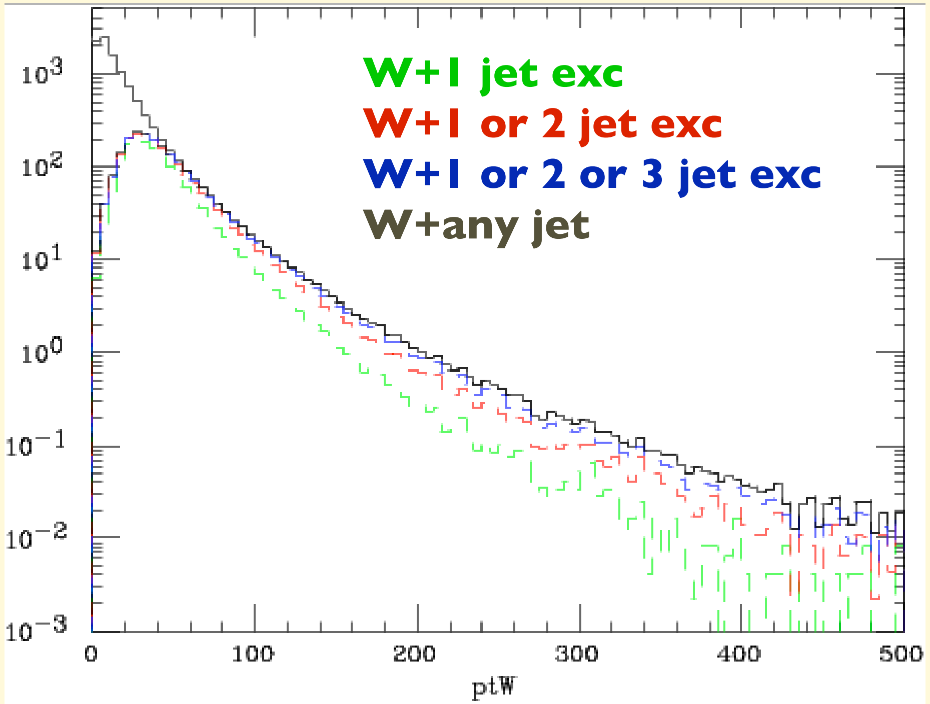
- Keep for inclusive sample **if the unmatched jet is softer than all matched ones**.
- Throw away otherwise, or for exclusive samples.

Validation of internal consistency:

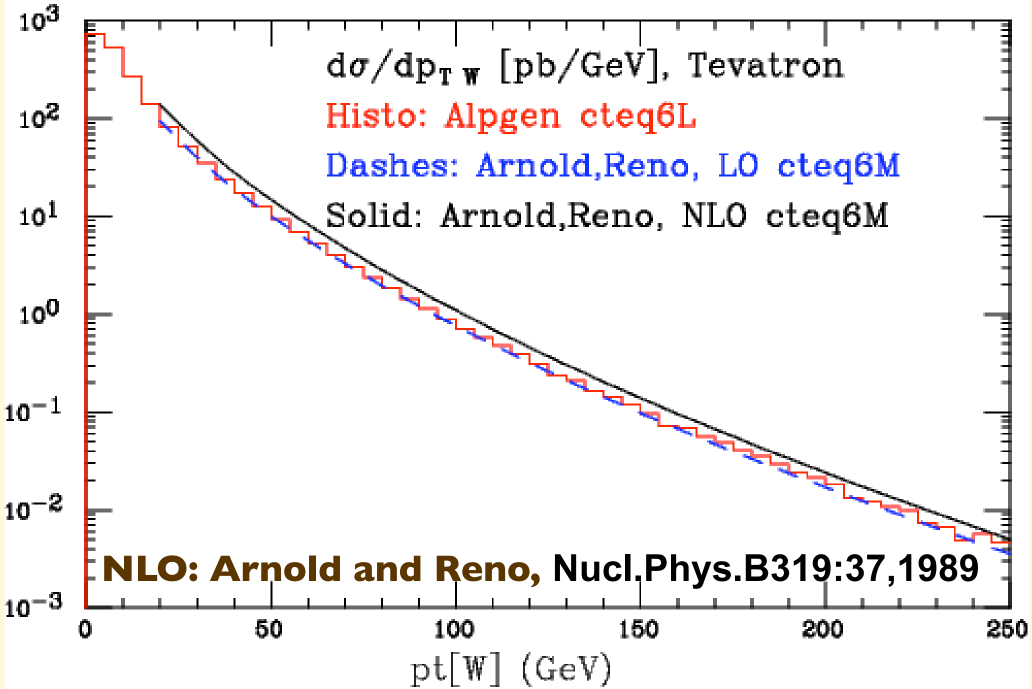
ME+shower with merging of multiparton MEs :

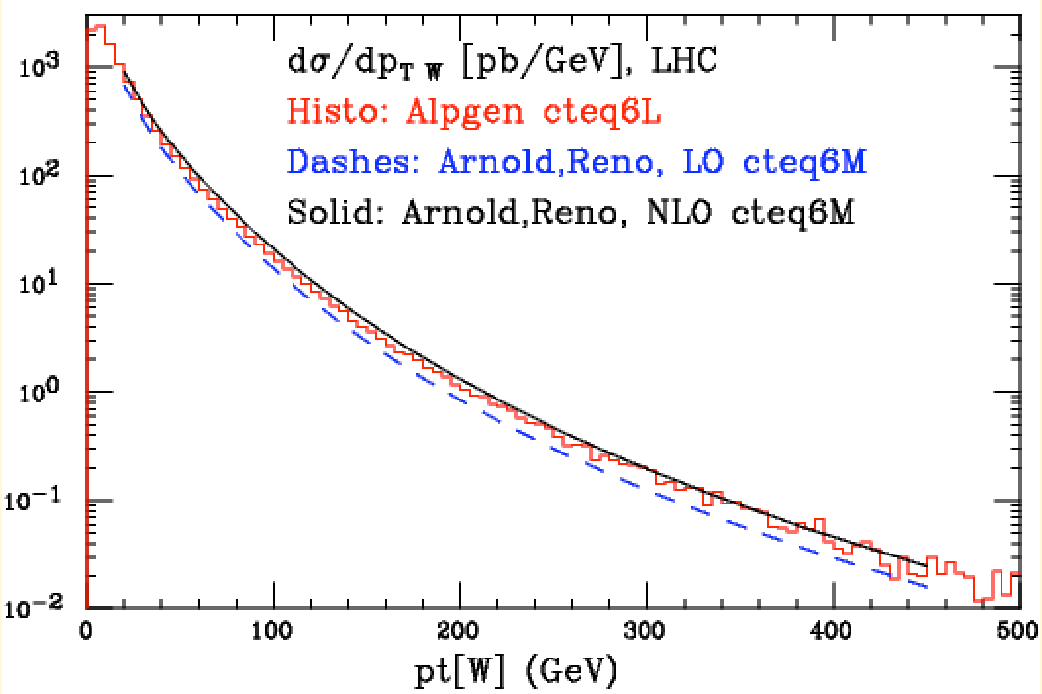
- The inclusive rate can be represented by the sum of multijet final state contributions: at high pt multijet final states dominate over the W + 1 jet rate!

- The matching algorithm carefully combines the independent multijet final states into a fully inclusive sample



Inclusive W pt spectrum, NLO vs LO MLM matching

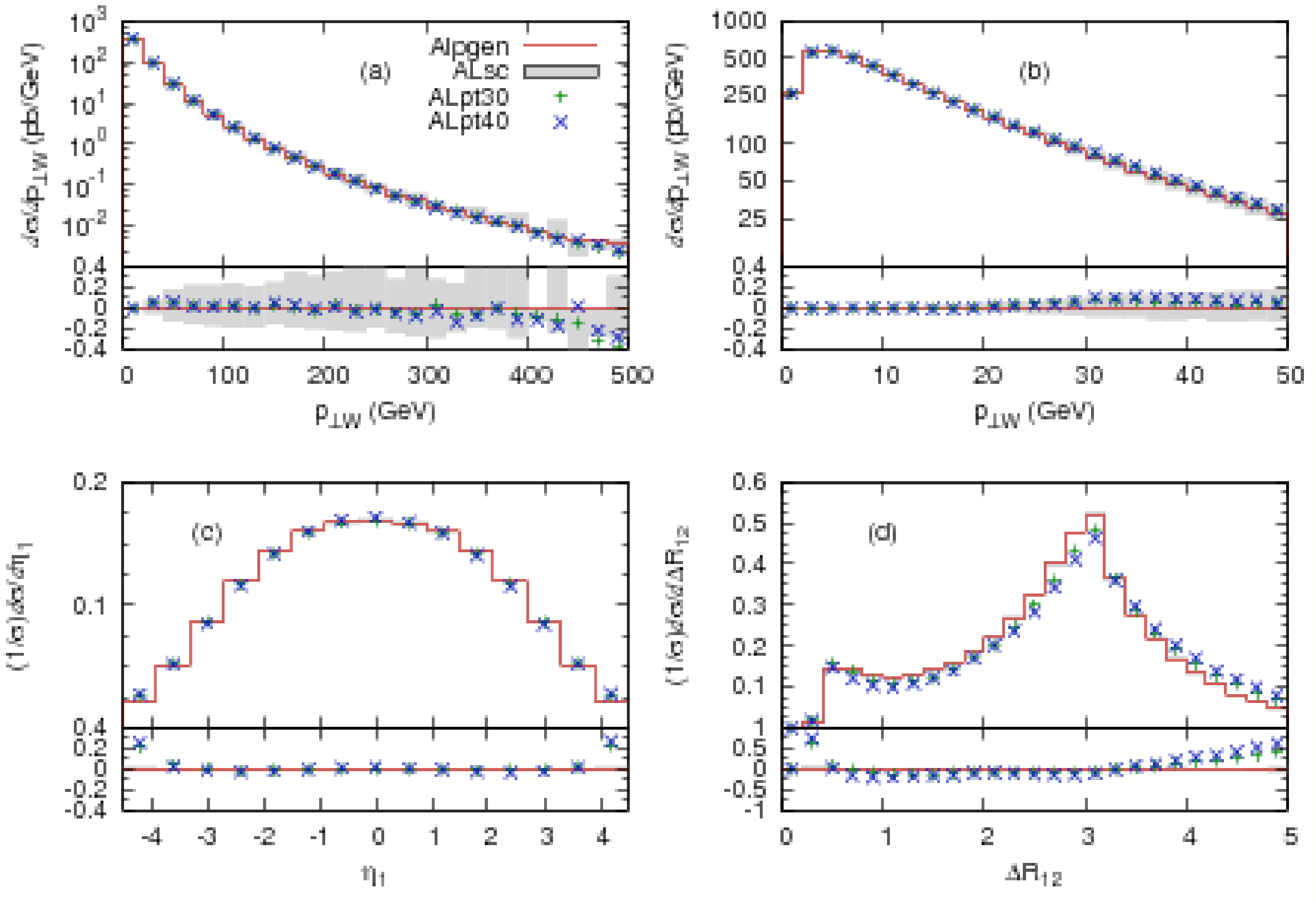




Examples of systematics studies (LHC Energy)

Comparative study of various algorithms for the merging of parton showers and matrix elements in hadronic collisions *

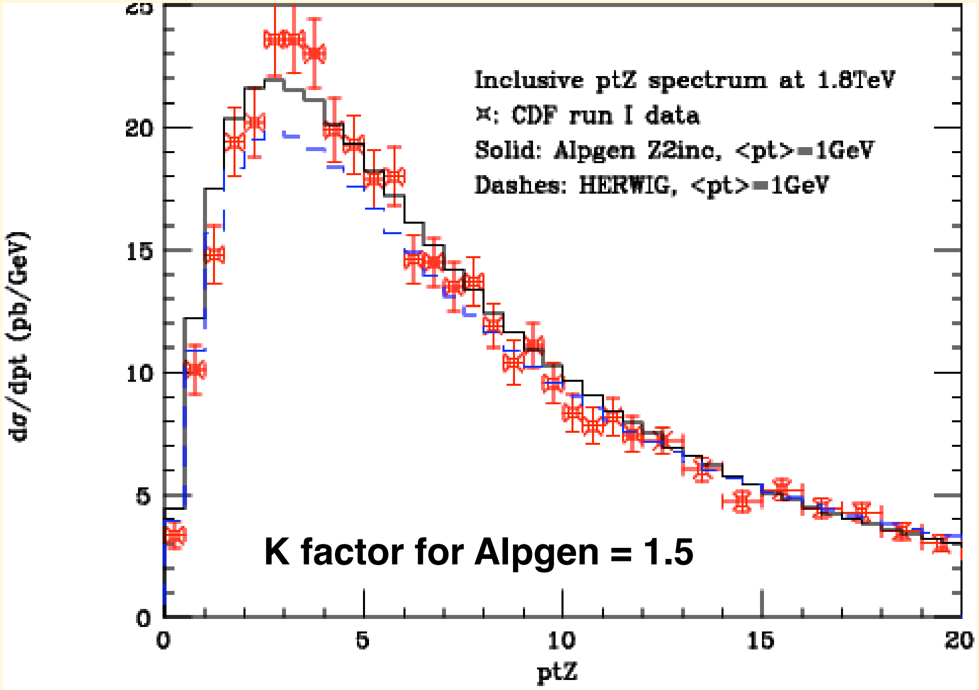
J. Alwall[1], S. Höche[2], F. Krauss[2], N. Lavesson[3], L. Lönnblad[3], F. Maltoni[4], M.L. Mangano[5], M. Moretti[6], C.G. Papadopoulos[7], F. Piccinini[8], S. Schumann[9], M. Treccani[6], J. Winter[9], M. Worek[10,11]

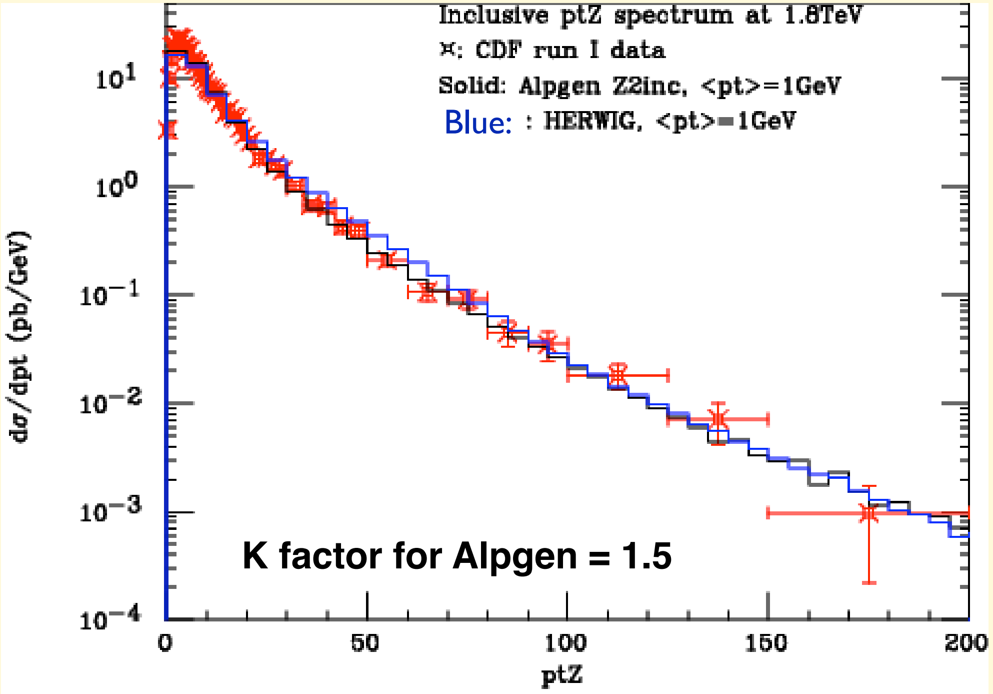


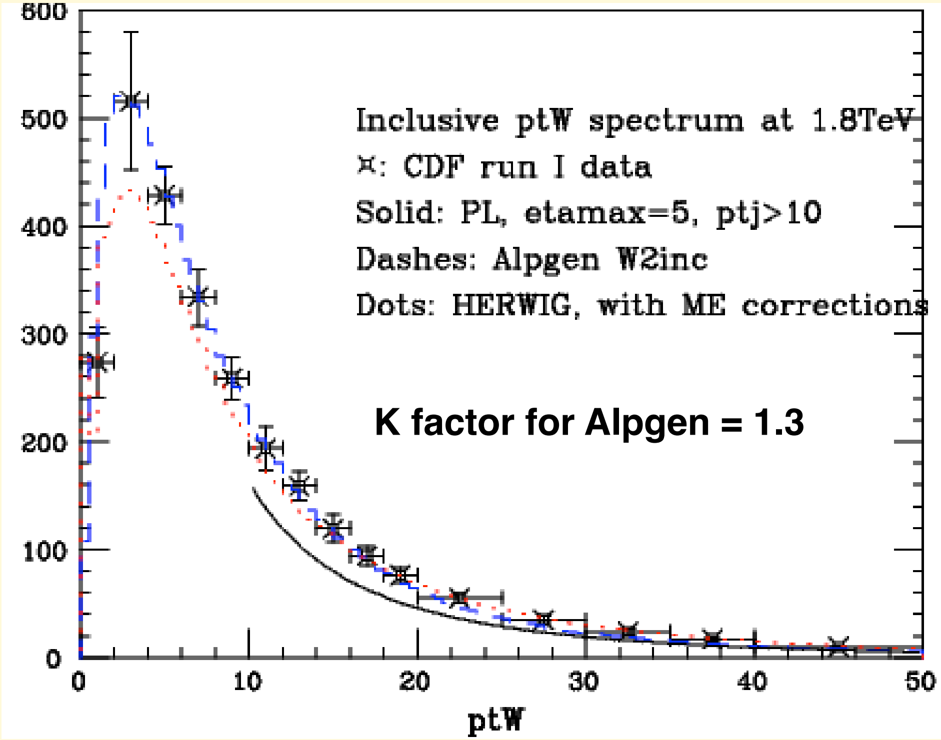
Different E_T matching thresholds: **20**, **30**, **40** GeV

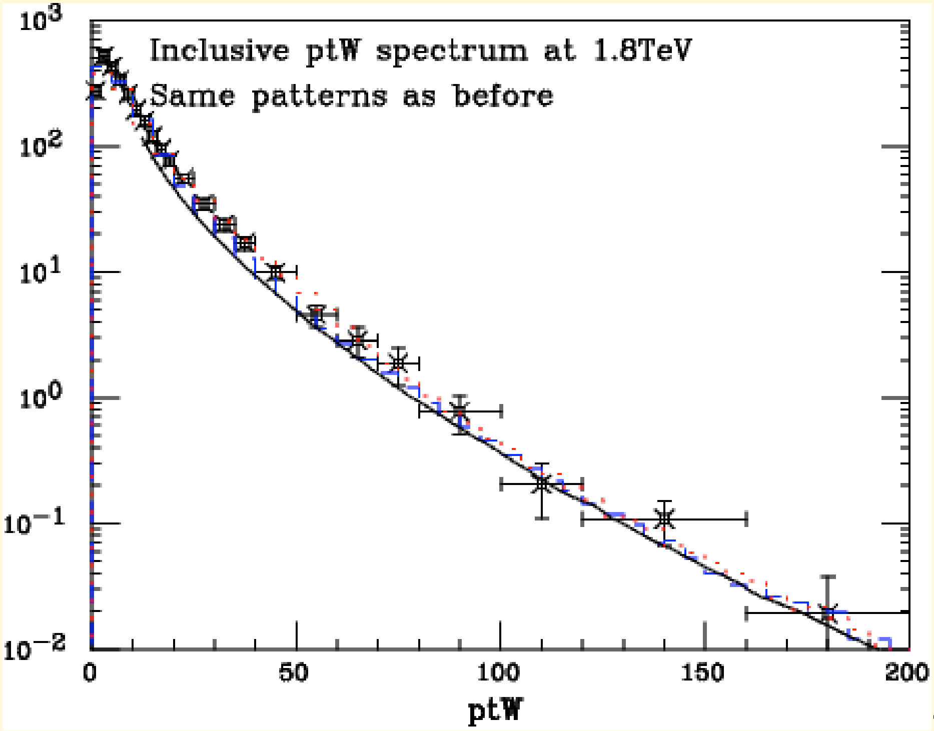
Different renorm. scale factor [0.5–2]=

Comparisons with data: Inclusive Z/W pt spectrum at 1.8 TeV (CDF data)



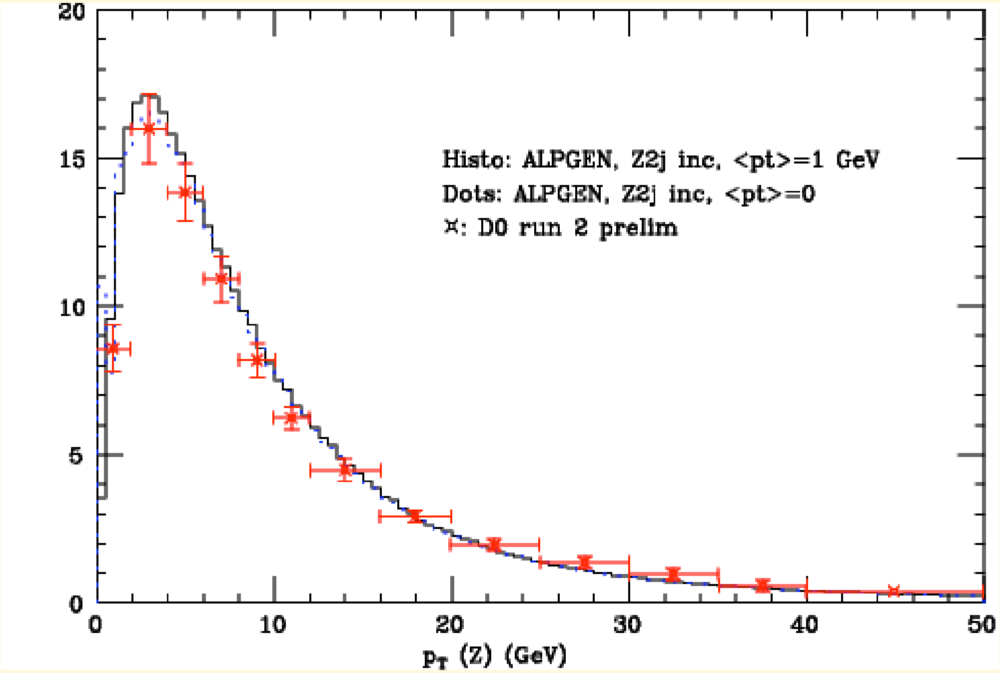


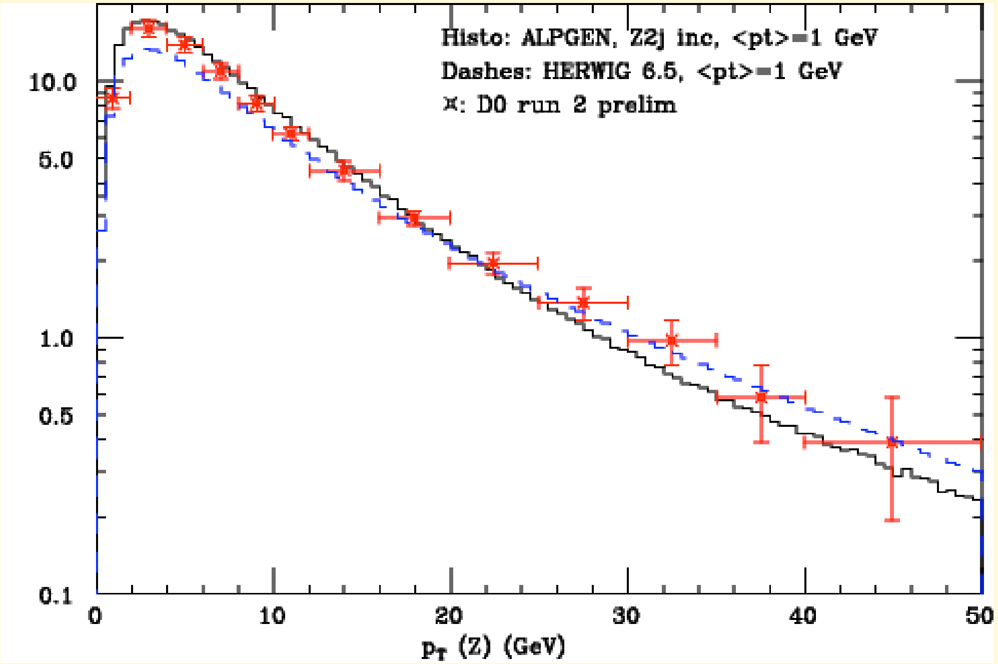


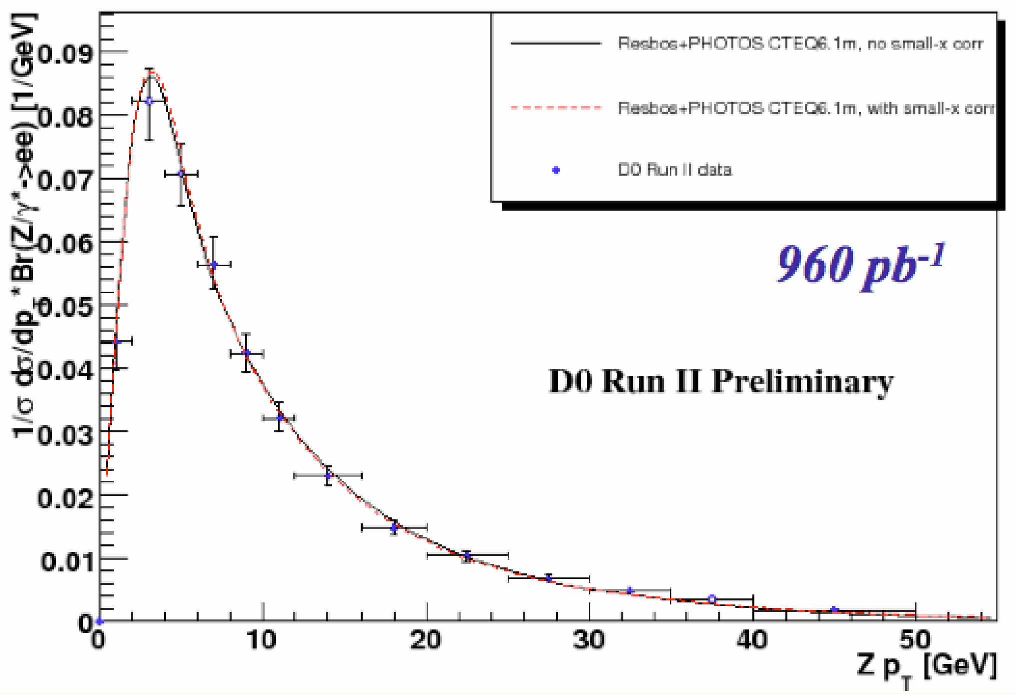


Comparisons with D0 data: Inclusive Z pt spectrum at 1.96 TeV

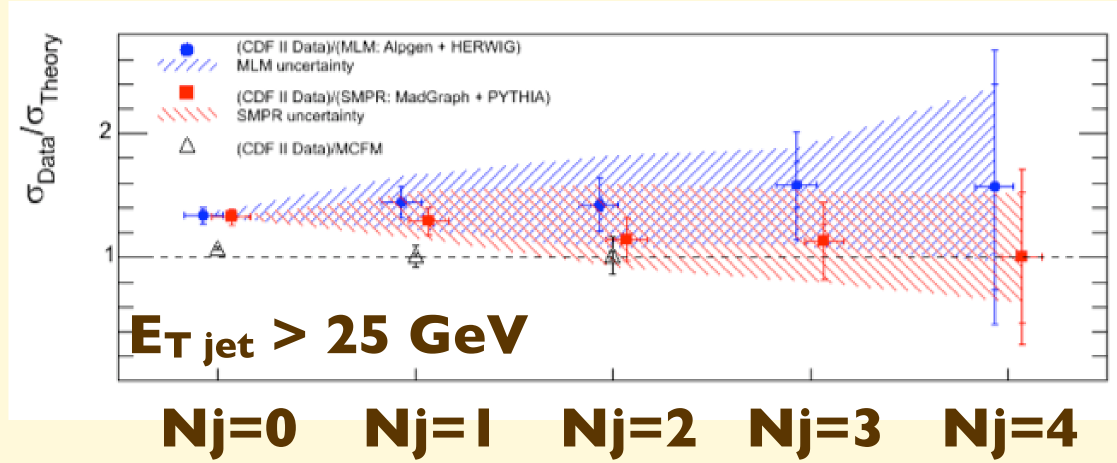
(D0 data: http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/EW/E18/E18.pdf)

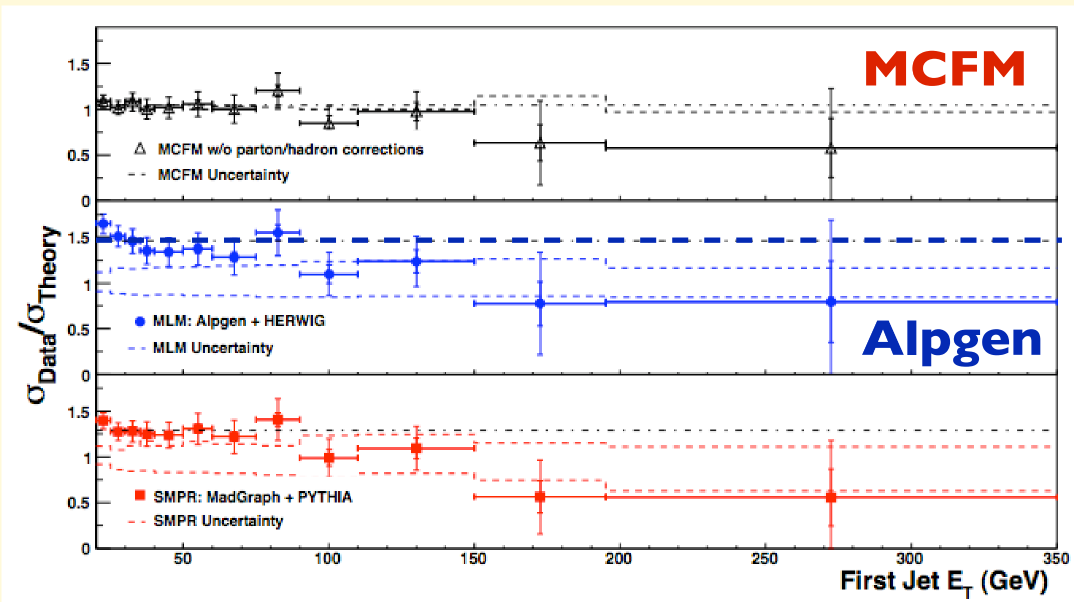


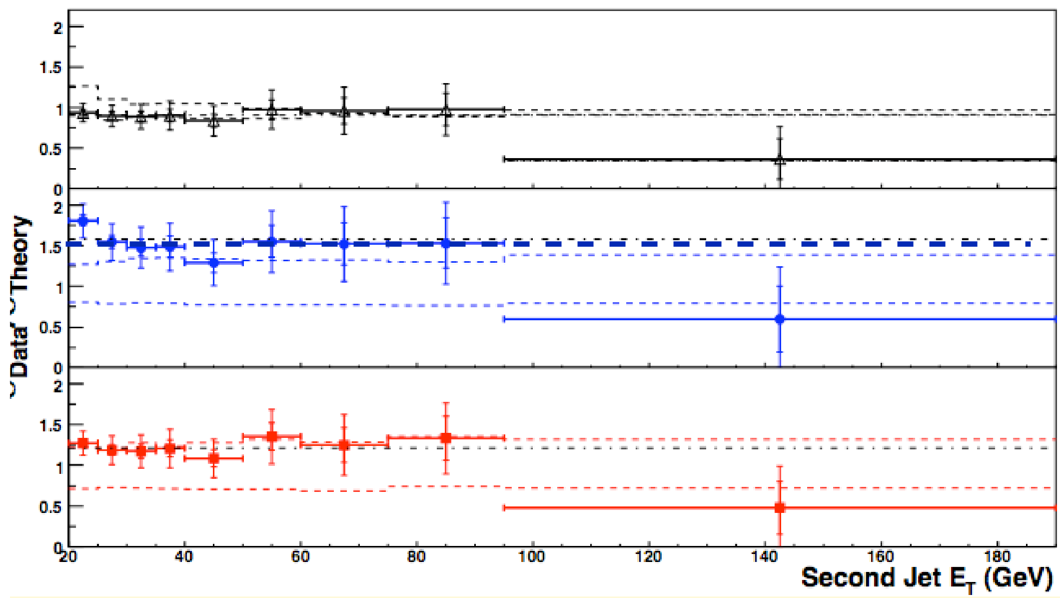


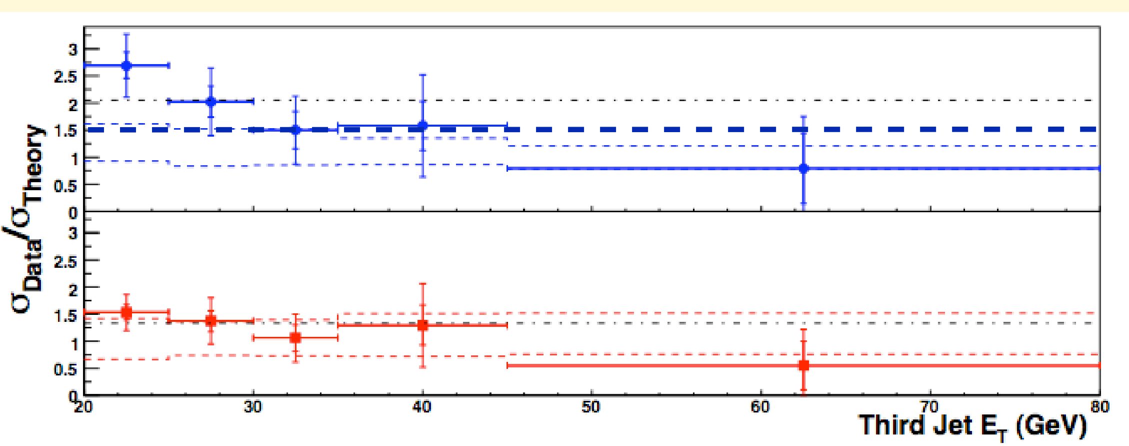


Jet spectra in W+jets
CDF, 380pb^{-1}

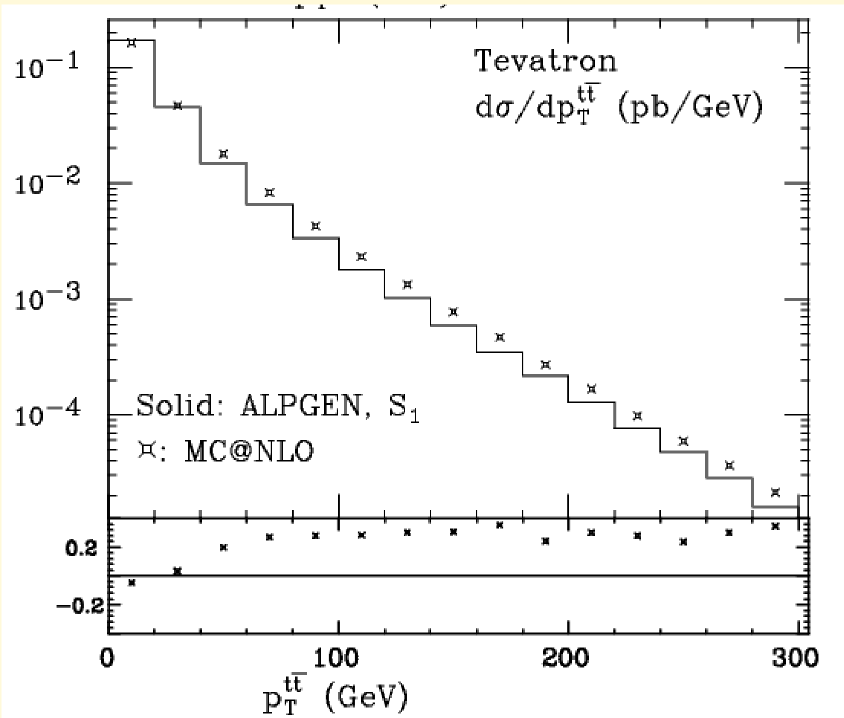


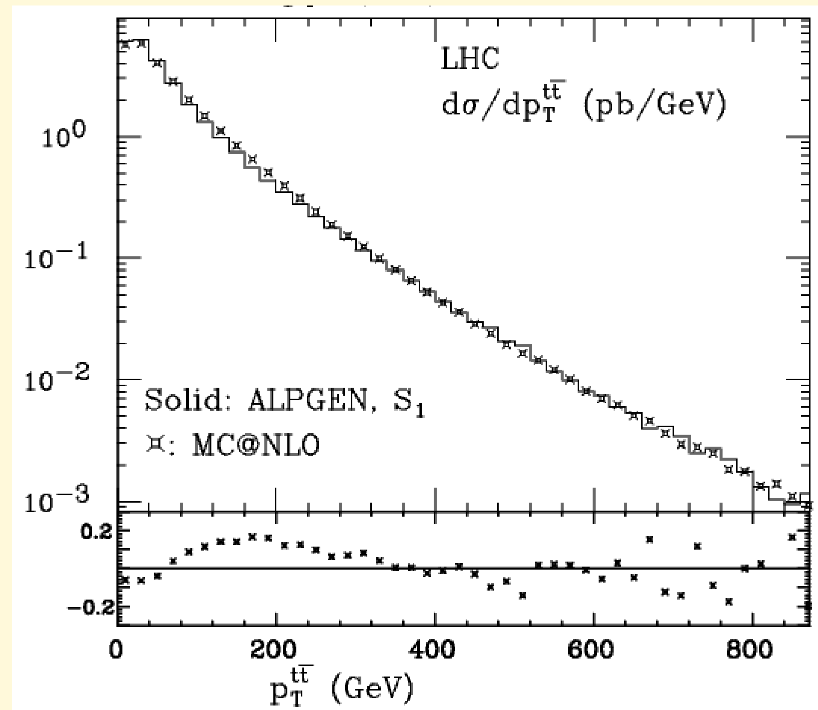






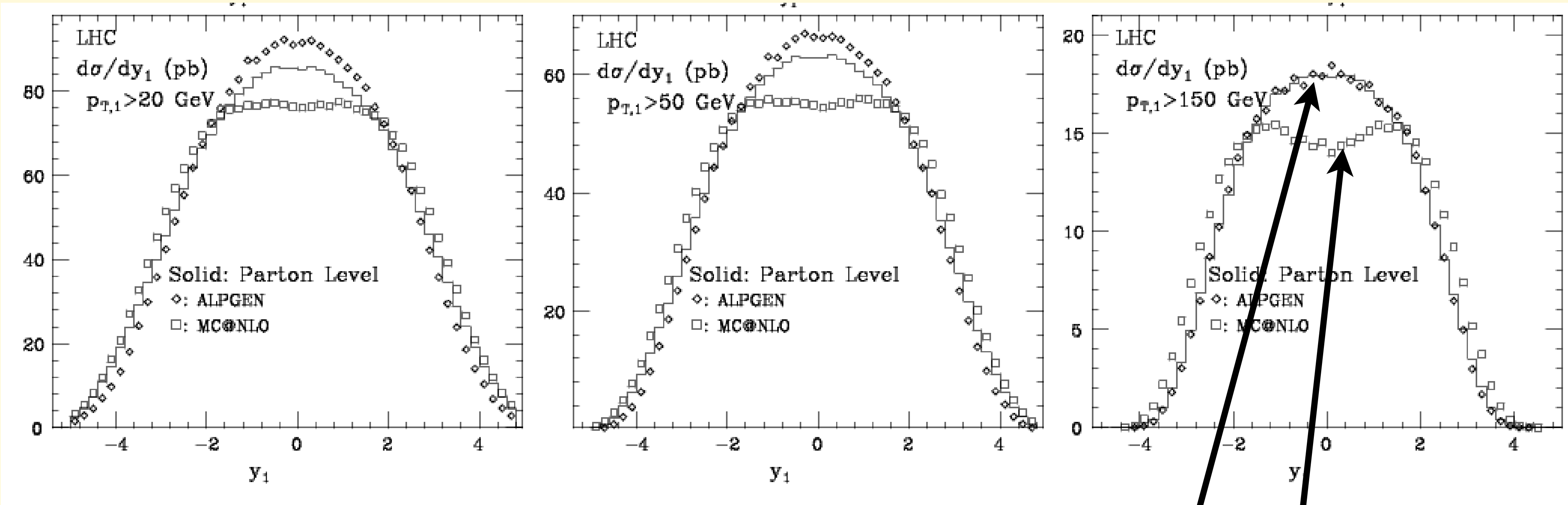
Comparisons with MC@NLO for t tbar final states





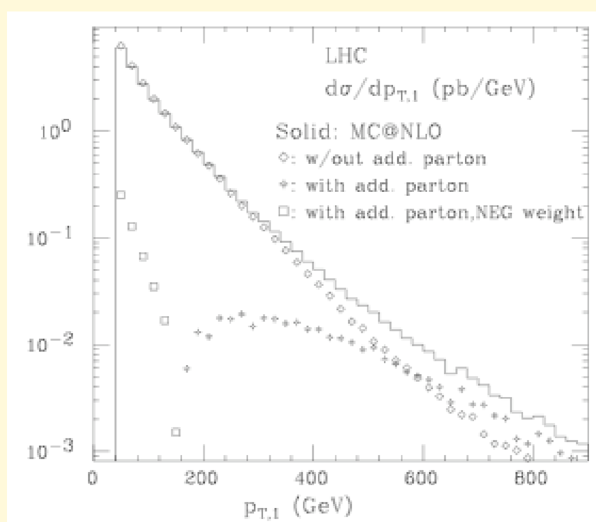
However ....

TeV



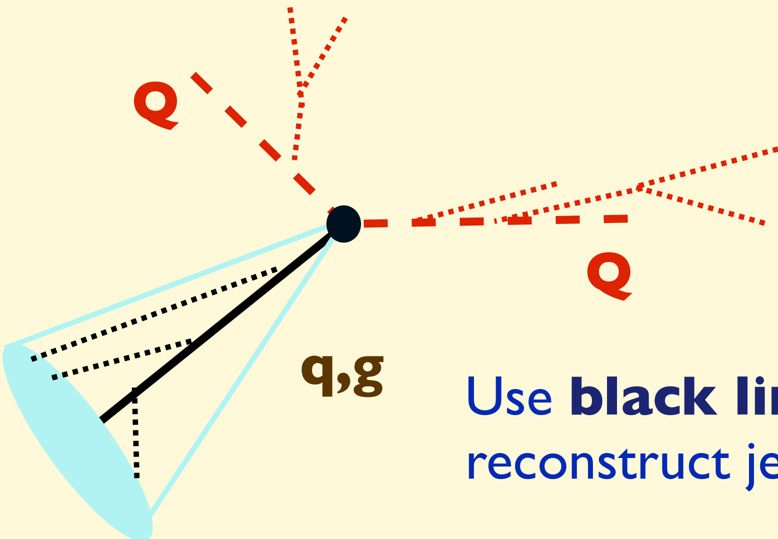
Large difference between **Alpgen or Parton Level** and **MC@NLO** jet rapidity spectrum even at ptjet > 150 geV

Origin of this effect:
Shower description of extra jet used up to pt~500 GeV! Central jet pruduction screened by shower dead-cone effect



Treatment of heavy quarks: final states

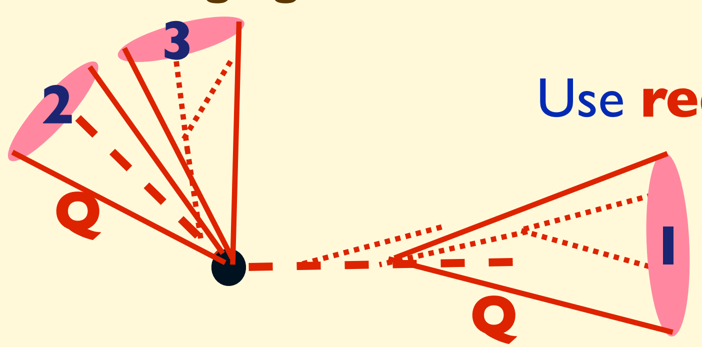
1st pass of merging prescription does not require matching of heavy quarks:



Leave **red lines** (hvq shower daughters) out of jet reconstruction

Use **black lines** (ISR+light-parton FSR) to reconstruct jets for matching

2nd pass of merging clusters the heavy quark shower daughters:



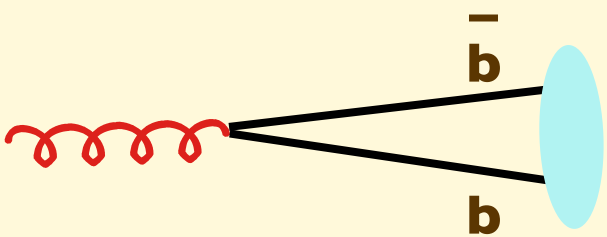
Use **red lines** only to reconstruct jets

* If jet contains the heavy quark itself (e.g. **1** and **2**), keep event
* If jet does not contain the heavy quark itself (e.g. **3**), treat it as extra jet:
  – reject event if exclusive sample
  – keep if E_T smaller than all matched jets

Comments

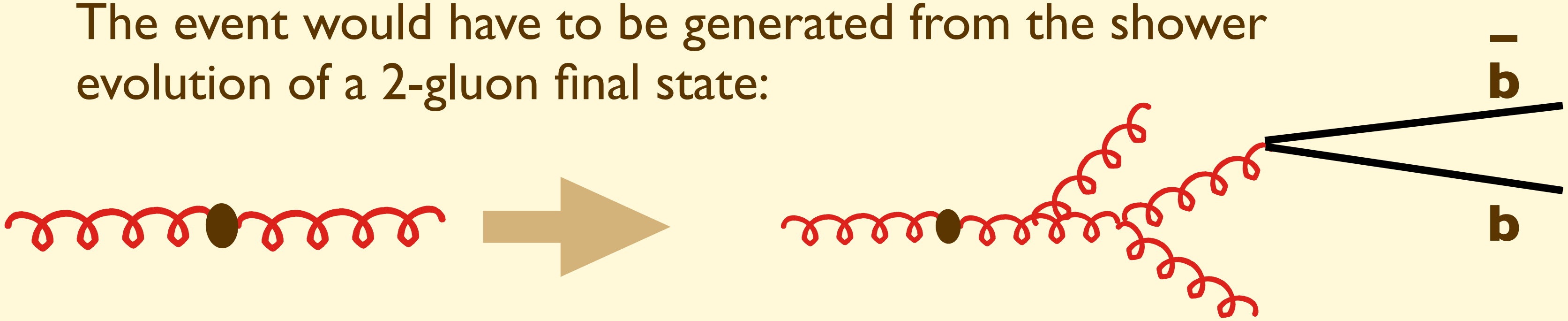
This prescription is used since HVQs can be generated in ALPGEN without cuts in p_T and in ΔR_{QQ}.

If we were to apply a matching cut on HVQs, we would e.g. reject an event with a final state like this:



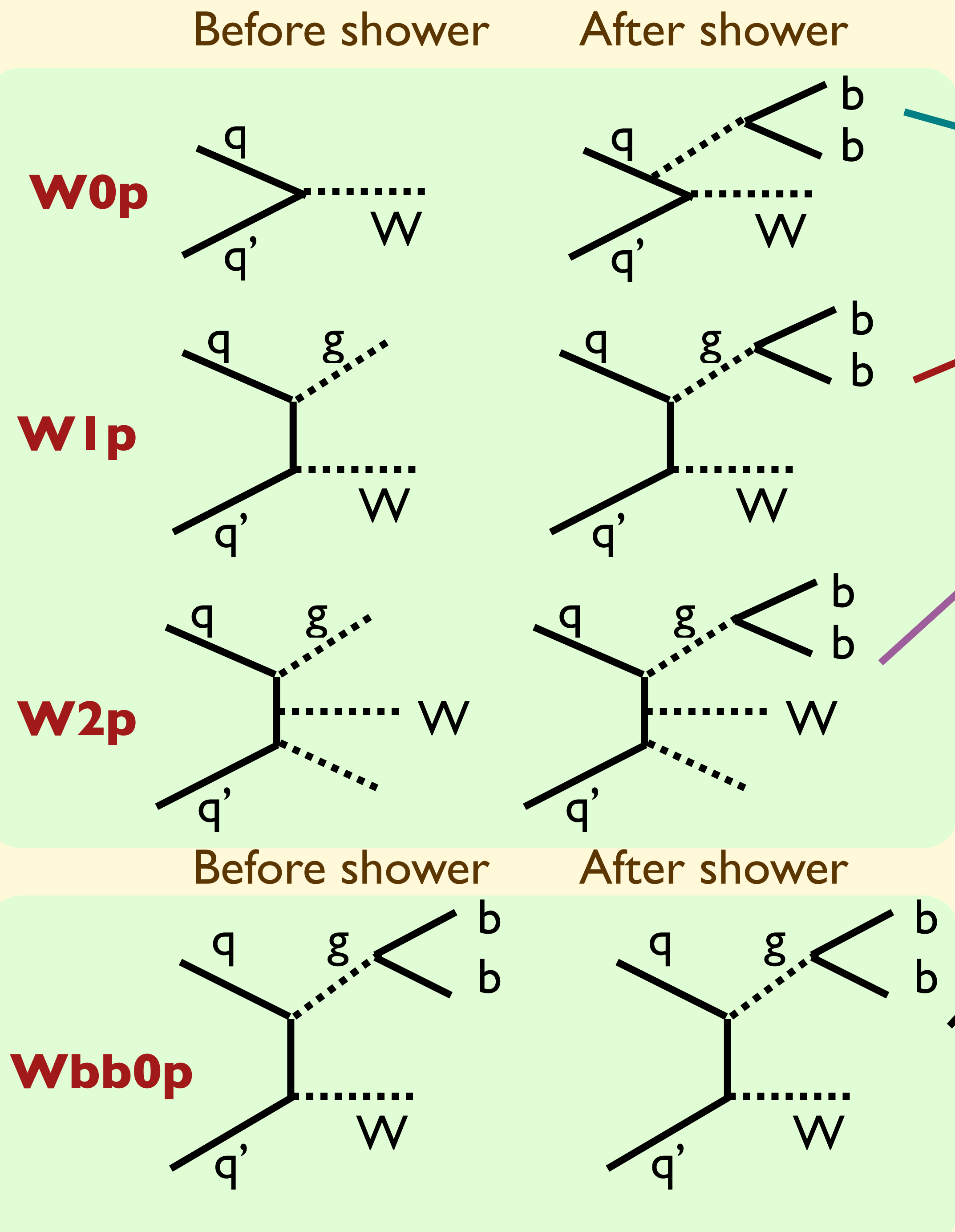
since both b and bbar match the same jet

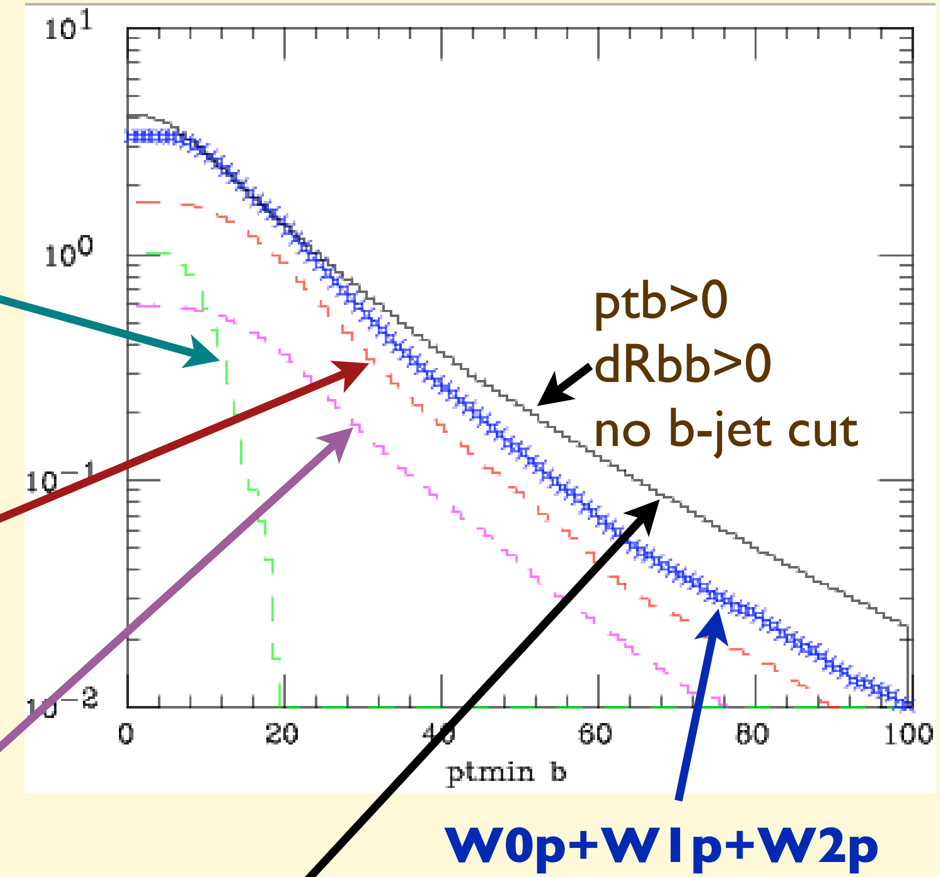
The event would have to be generated from the shower evolution of a 2-gluon final state:



=> great loss of efficiency, need to mix samples from different processes, ...

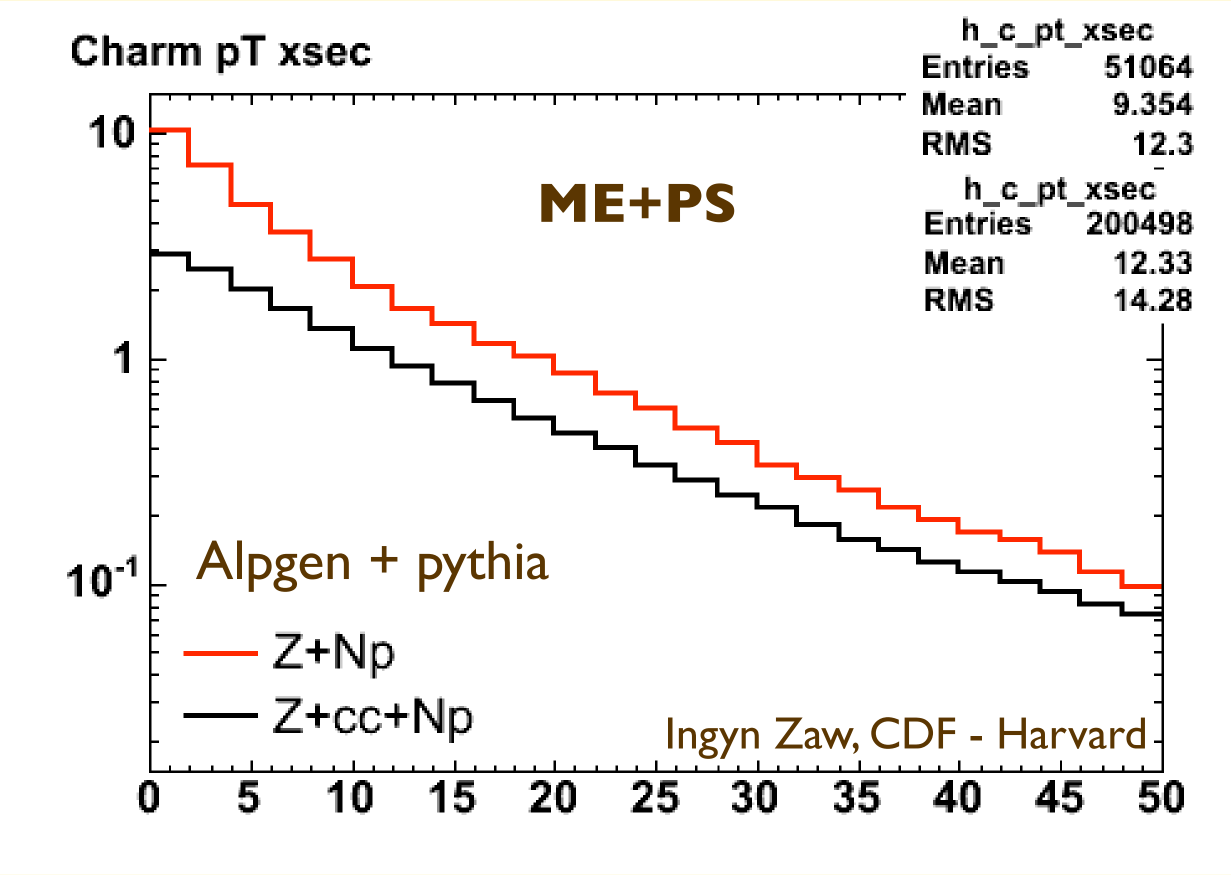
Ex: Wbb vs W[g→bb]





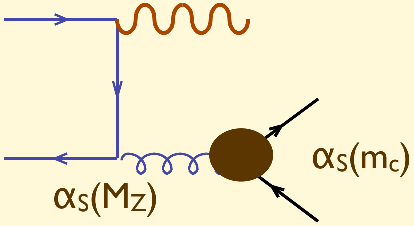
In the case of Wcc the differences are larger

Example, shower vs ME description of charm in Z + c cbar + jets



Z+Np ⇒ Matrix elements for Z +

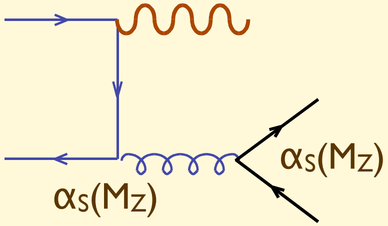
N light partons, with g→c cbar from the shower evolution



σ[Zcc] ~ $\alpha_S(M_Z) * \alpha_S(m_c)$

Z+cc+Np ⇒ Matrix elements for Z +

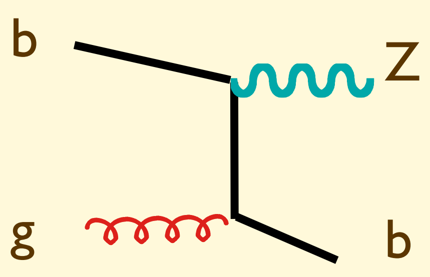
c cbar light partons, followed by shower



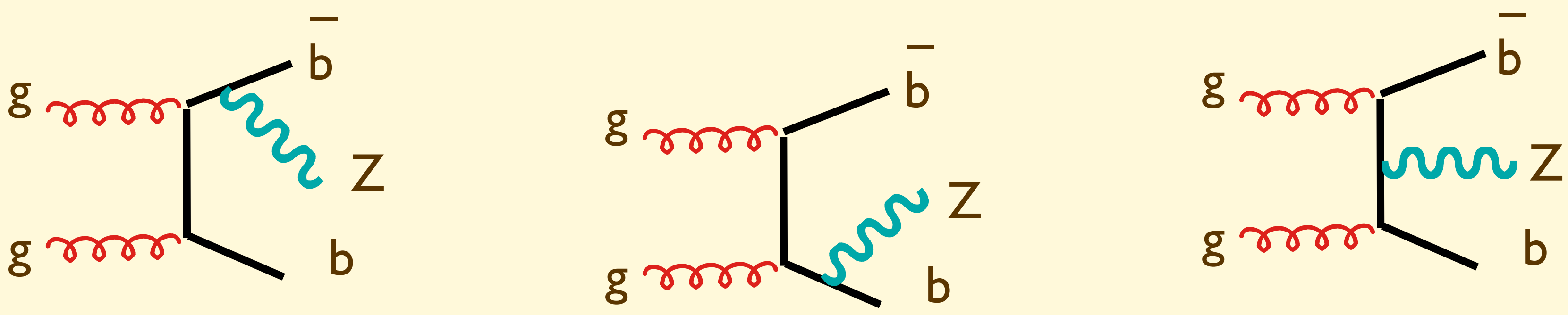
σ[Zcc] ~ $\alpha_S{}^2(M_Z)$

Treatment of heavy quarks: initial states

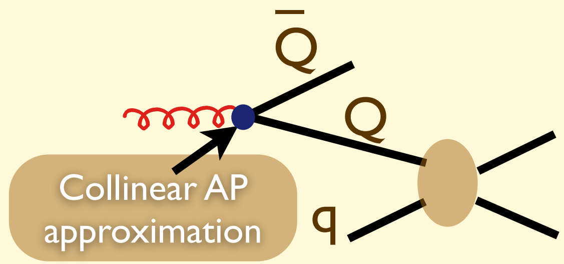
In ALPGEN heavy quarks never appear in the initial state. Processes with initial-state HVQs are produced by higher-order diagrams with initial-state gluon splittings

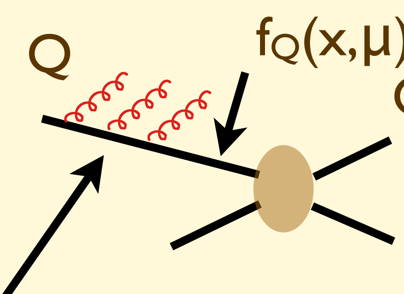


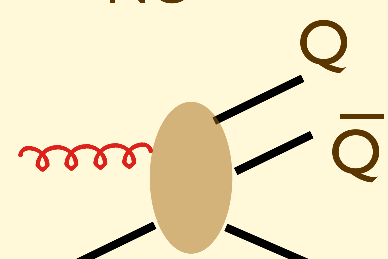
➡ **in Alpgen:**



Pro and cons of the two approaches:

Features:	Massless PDF approach	Massive ME approach
Exact massive kinematics and phase-space onset	NO	YES
Description of recoiling hvq		Full ME
Availability/easiness of NLO results	V	–
Accuracy w.r.t. possibly large higher-order logs	YES	NO

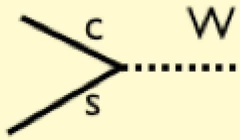




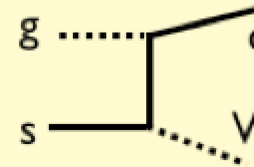
$$\frac{d\,f_Q(x,\mu)}{d\log\mu^2} = \frac{\alpha_s}{2\pi}\left[P_{Qg}\otimes g(\mu) + P_{QQ}\otimes f_Q(\mu)\right]$$

Example: c sbar → W

σ (



) $\sim \int dp_T \, \frac{d\sigma}{dp_T}$ (



)

?!

σ[c s → W] = 110 pb $\Leftrightarrow$ **$\int dp_T \, \sigma$[gs → cW] = 45 pb**

Very large difference between the two approaches for this specific process

The understanding of this difference is work in progress (MLM, maltoni, campbell, tramontano)

Wc cross section at CDF

- The Wc Production Cross Section has been measured using SLT tagging in the W+1,2 jets
  - Integrated Luminosity: ~1.8fb^{-1}

$$\sigma_{Wc}(pt_c > 8, |\eta_c| < 3) \times BR(W \to \ell\nu)$$

$$= 28.5 \pm 8.2(\mathrm{stat})^{+4.0}_{-4.3}(\mathrm{syst}) \pm 1.7(\mathrm{lum})\ \mathrm{pb}$$

  - The result is in good agreement with the theoretical prediction, which is
    - σ(Wc; charm pt>8, $|\eta|$<3) = 22.2 ± 1.2 [PDF] + 3.8/-3.0 [scale]
    - NLO contributes 40% more (excluding Wcc).

ALPGEN, LEADING ORDER

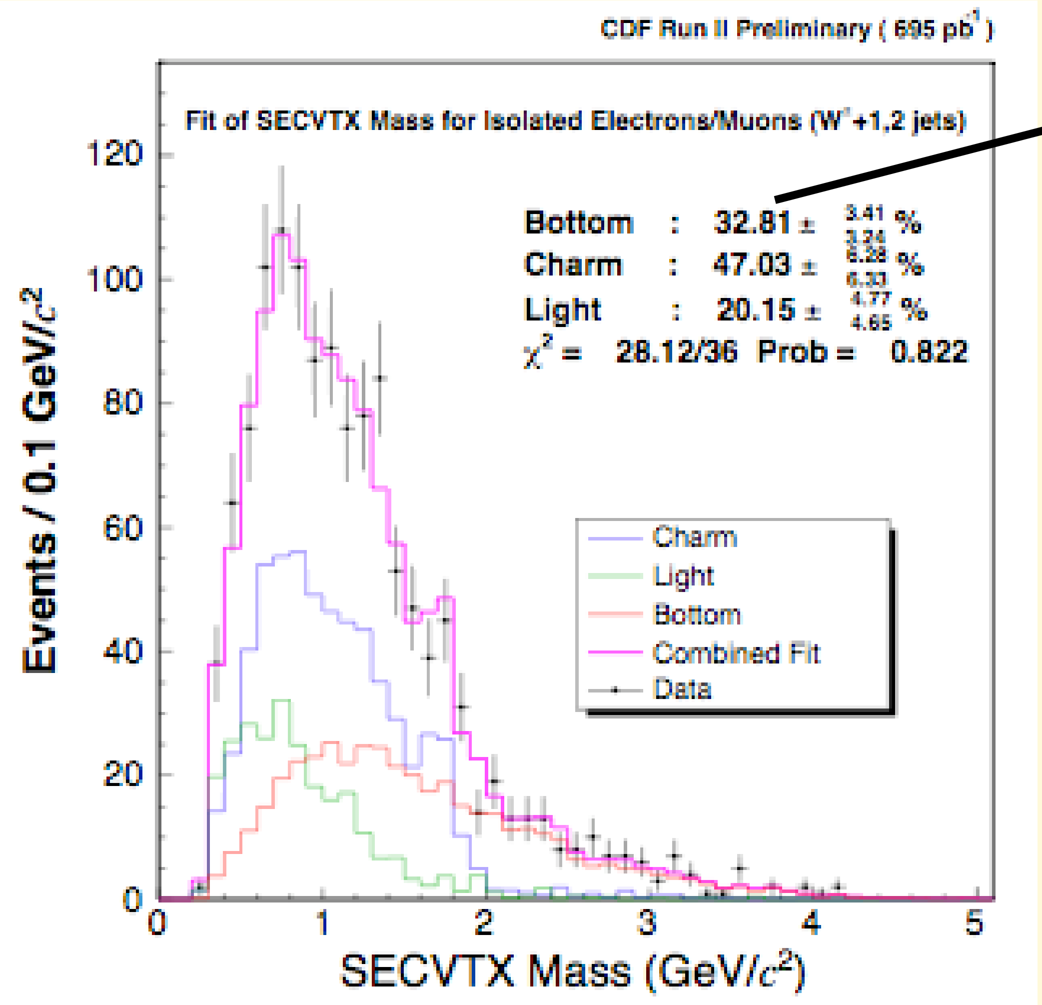
Wbb cross section, CDF data vs Alpgen

http://www-cdf.fnal.gov/physics/new/top/confNotes/cdf8410_wbb_public_note.pdf

p_T^{lept}
$E_T^{jet} \geq 20$ GeV
$|\eta^{lept}| \leq 1.1$

$|\eta^{jet}| \leq 2$

MET $\geq$ 25 GeV



416±43 b-tagged jets, of which

123 from other EW sources, and mostly ttbar and single top

103 from QCD (non-W)

The analysis with greater luminosity will allow to study the b-jet E_T spectrum as well

CDF: σ[Wbb] = 0.90±0.20±0.26

Alpgen: σ[Wbb] = 0.74±0.18

Important message

We still don't have data suitable for appropriate tuning of the tools:

– typically jets in WZ+jets not corrected to detector level*, to be compared directly to a theoretical calculation

– lack of validation of UE structure in W/Z+multijet final states (tunings á la R.Field may not work for codes with multijets)

– low statistics for W/Z+ heavy quarks (e.g. to probe jet E_T spectra)

– still difficult to separate different components to W/Z+tagged-jets (Wbb vs Wcc vs Wc)

Looking forward to the imminent release of analysis updates from CDF/D0 with O(2 fb^{-1})

* except CDF 350pb^{-1} W+multijet analysis