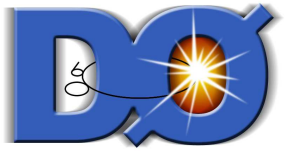
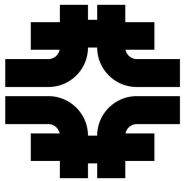
ME/PS Matching Studies in DØ



Daniel Wicke
(Fermilab)



Outline

- Introduction
- MLM
- CKKW
- Summary

Introduction

- Parton shower models
  - good in describing jet evolution, i.e. for soft radiation.
  - restricted to $2 \longrightarrow 2$ hard processes.
- Matrix element models
  - good in describing hard interactions.
  - no description of jet evolution (soft radiation).
- Analyses with many hard final state particles (including jets) need both.

Simple connection leads to double counting, elaborate matching is required:

- CKKW: Restrict PS to cover only phase space not covered in ME.
- MLM: Identify and reject "double counting" events.

This talk shows findings made with such matched MC samples in DØ.

MLM Matching

Prescription (Reminder)

1. Generate events of given multiplicity according to Matrix Element with cuts on p_T and/or spacial distance (e.g. ΔR_{cone}).

2. Perform parton shower (e.g. with Pythia or Herwig)

3. Process showered event *before hadronisation* with a jet algorithm

4. Match partons (from 1) with jets (from 3)
   - Exclusive: Each parton is matched to exactly one jet and vice versa.
   - Inclusive: Each parton is matched to a jet (unassociated jets may exist).

5. Combine samples with differing ME multiplicity (constant luminosity):
   - use exclusive matched events except for the last multiplicity bin.
   - e.g. $W + N = W{+}0\mathrm{j}|_{\mathrm{excl}} \oplus W{+}1\mathrm{j}|_{\mathrm{excl}} \oplus \ldots \oplus W{+}4\mathrm{j}|_{\mathrm{excl}} \oplus W{+}5\mathrm{j}|_{\mathrm{incl}}$

Implementation

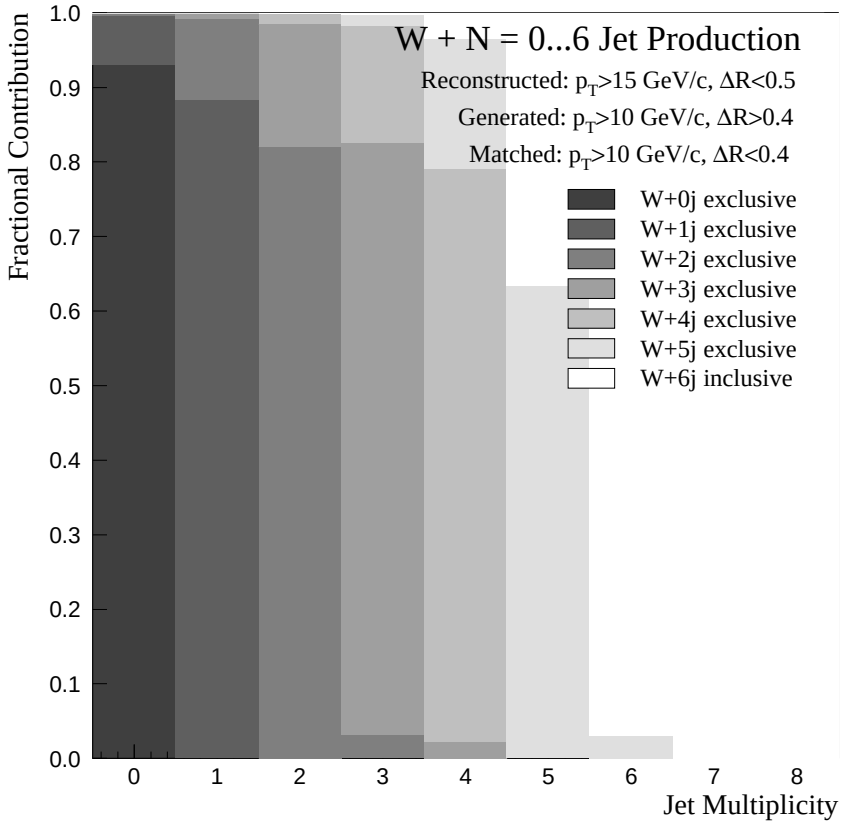
"Match after the fact", i.e. MLM rejection done after full simulation (if any).

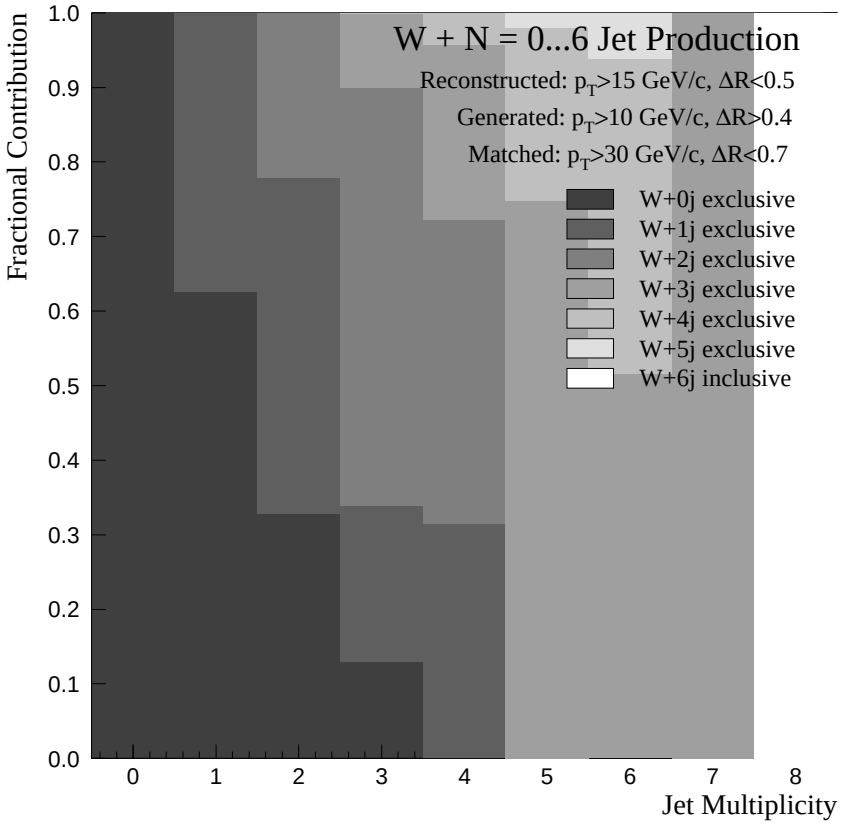
- Allows "reuse" of unmatched samples.
- Allows application of various matching parameters.
- Low matching efficiency requires high statistics w/ full detector simulation.

Samples created

- Alpgen + Pythia (W+jets or Z+jets samples)
- Alpgen generation cuts include: $p_T > 8\,\text{GeV}$ and $\Delta R > 0.4$
- Varying cone jet parameters: $p_T = 10, 20, 30\,\text{GeV}$ and $\Delta R_{\text{cone}} = 0.4, 0.7$
- Vary highest multiplicity taken from ME: $N_{\text{jets}}^{\text{gen}} \leq 0 \ldots 4$
- 30 samples per process (W+jets, Z+jets, etc.)
- Results should be independent of exact matching parameters.

Where do the events come from?





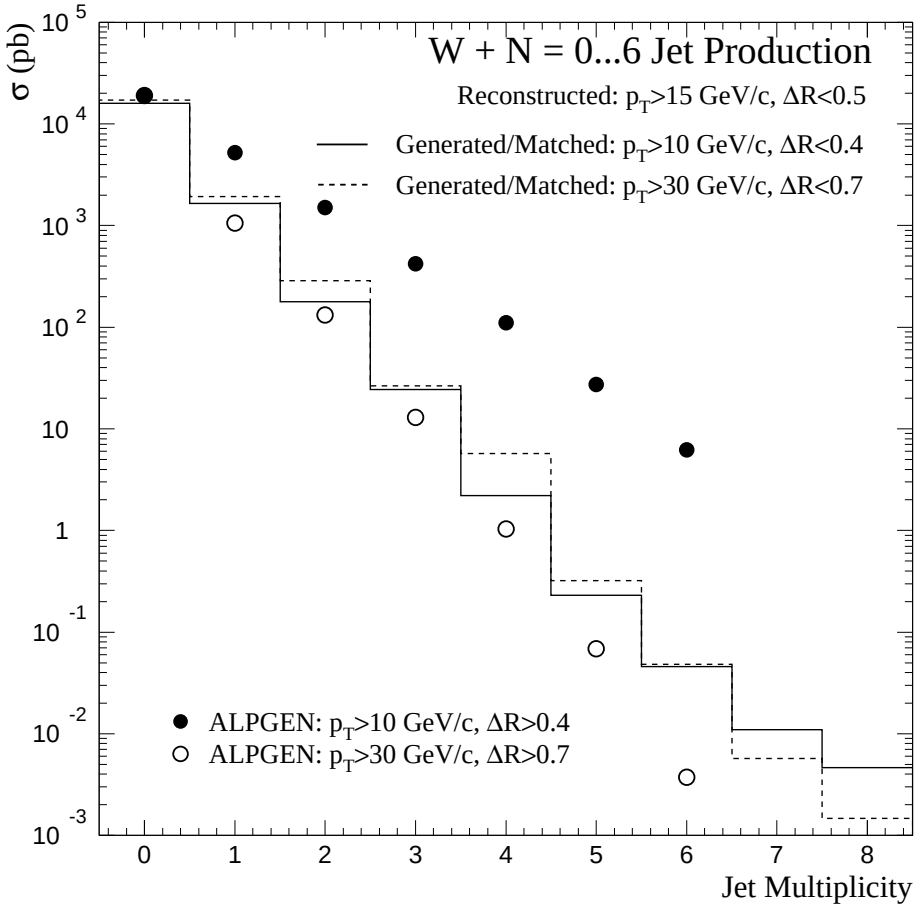
Event mixture (by multiplicity bin) is strong function of matching criteria.

Important for requesting sample statistics.

Gen.	p_T,ΔR, N	
Mult.	10,0.4,i4	30,0.7,i4
0	$\sim 90\%$	$\sim 90\%$
1	20%	4.7%
2	5%	0.8%
3	0.7%	0.03%
4	0.1%	0

Stability wrt. matching cirteria

- Result should not depend on the generator cuts or matching criteria.
- Matched result lies between the generated cross sections and displays different multiplicity dependence.



W+jets (Muon channel)

Analysis Selection

$t\bar{t}$ cross-section analysis in l+jets channel (topological selection).

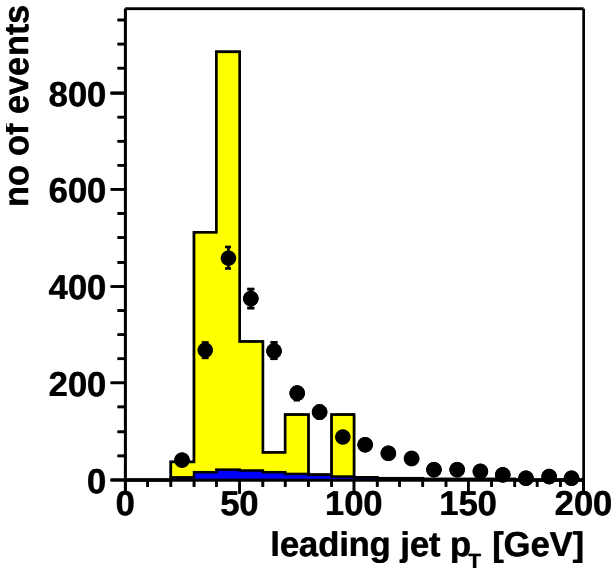
Isolated high p_T muon.

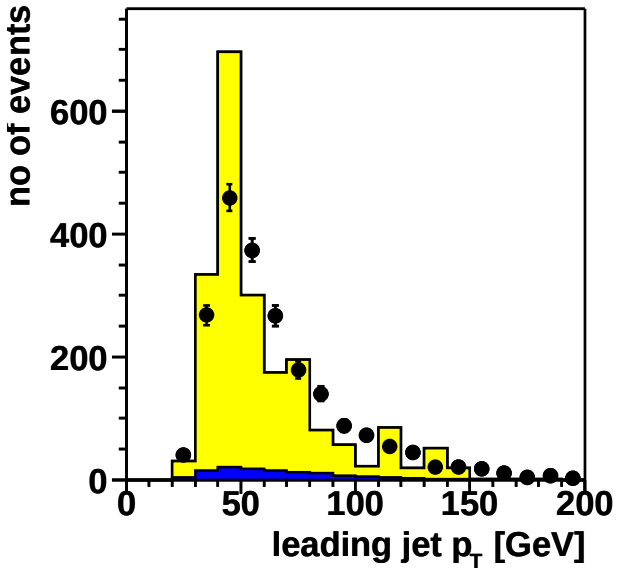
$E_T^{\mathrm{miss}} > 20\,\mathrm{GeV}$

$|\eta| < 2.5$

Here: 2 jets $p_T > 20\,\mathrm{GeV}$ (more lacks MC statistics)

p_T spectra for various inclusive bins

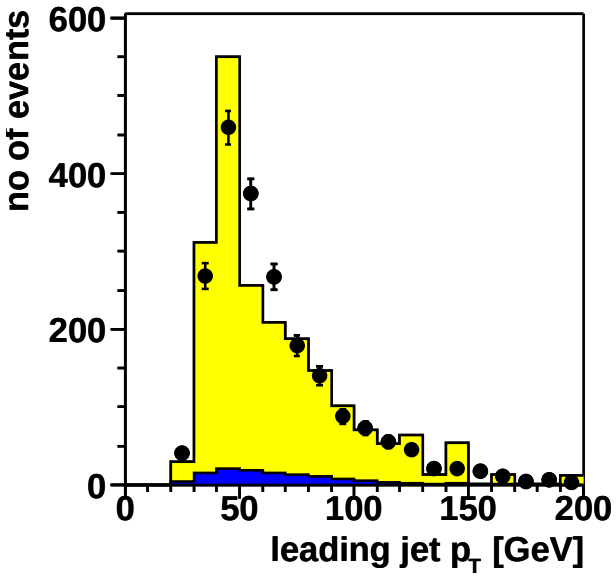


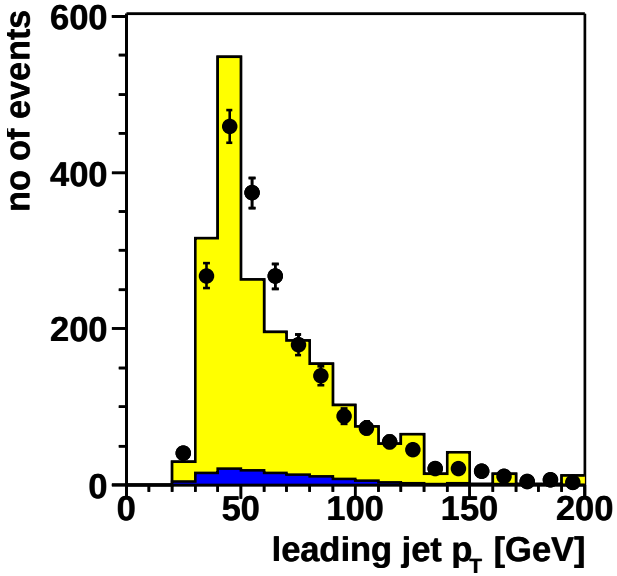


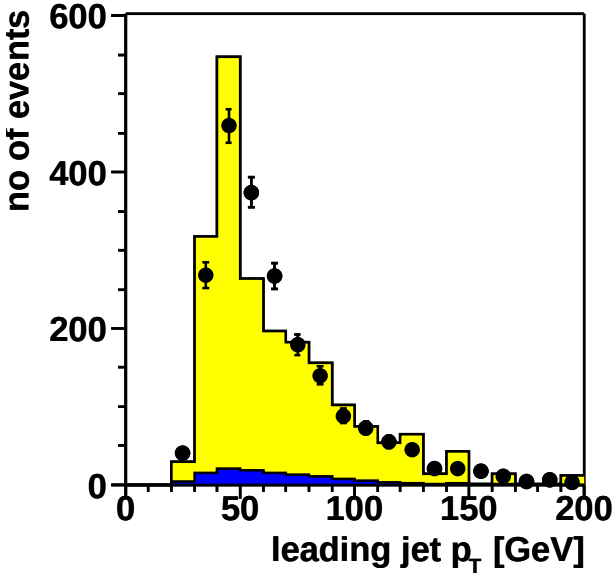
$\leftarrow$ $N = 0, 1$ too soft.

2091 Evt. data
0 % ttbar
94 % W+jets
6 % QCD

$\downarrow$ $N = 2, 3, 4$ better.

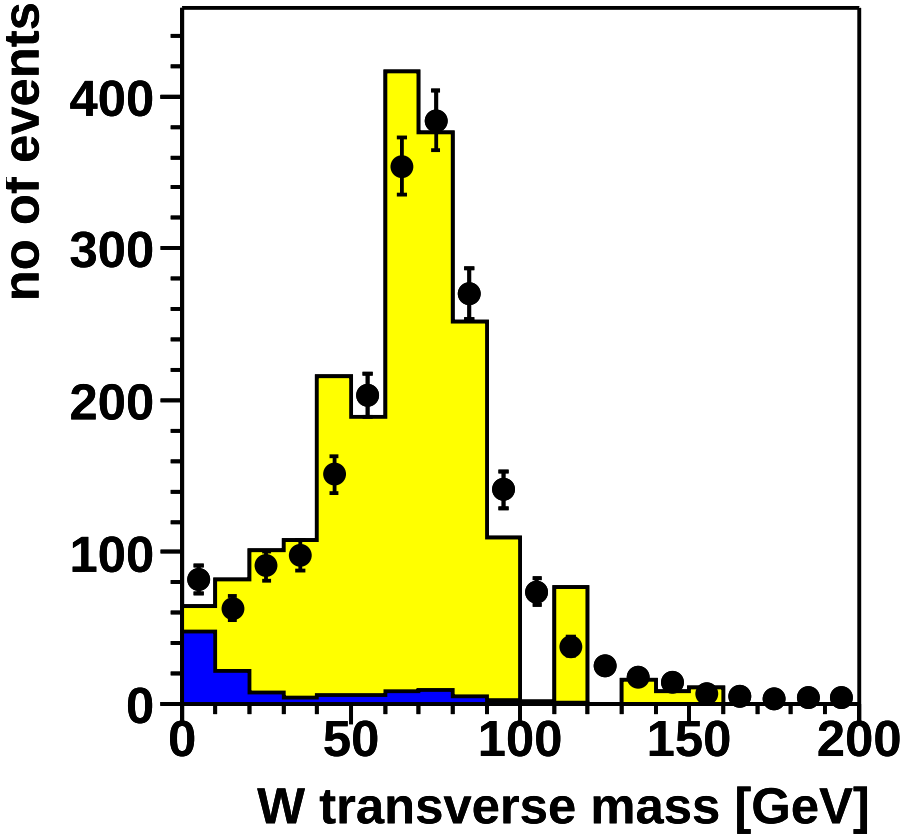




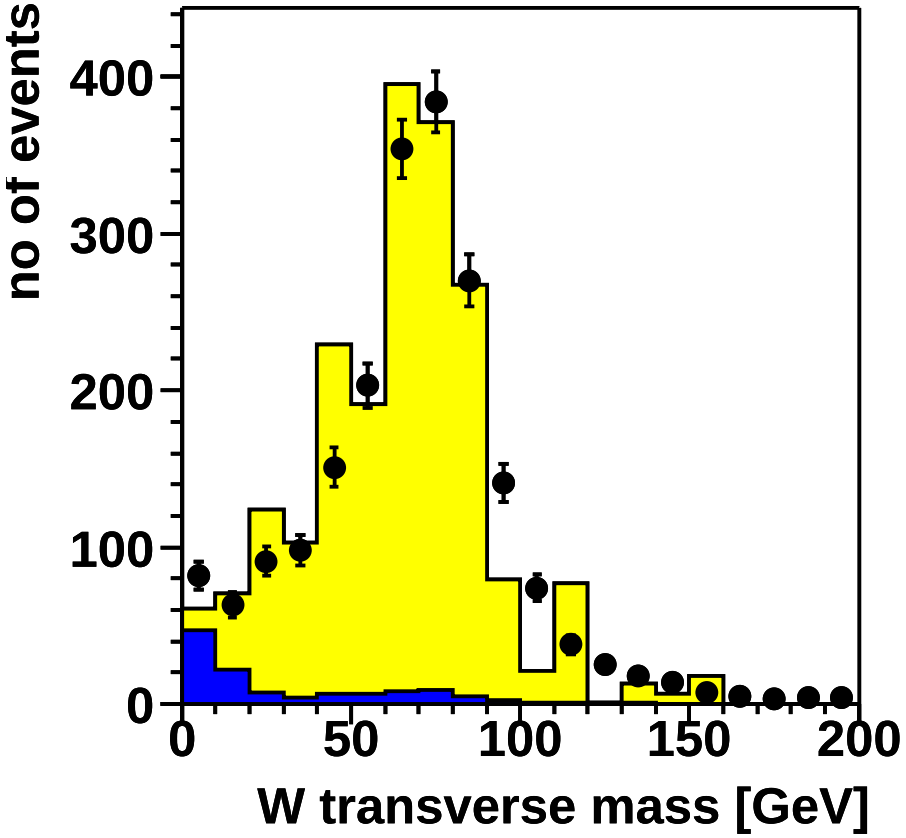


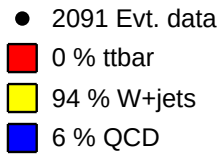
W transverse mass.

$\Delta R = 0.4$



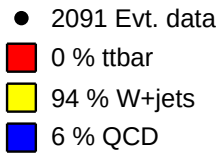
$\Delta R = 0.7$





$\Delta R = 0.4, 0.7$ look the same.

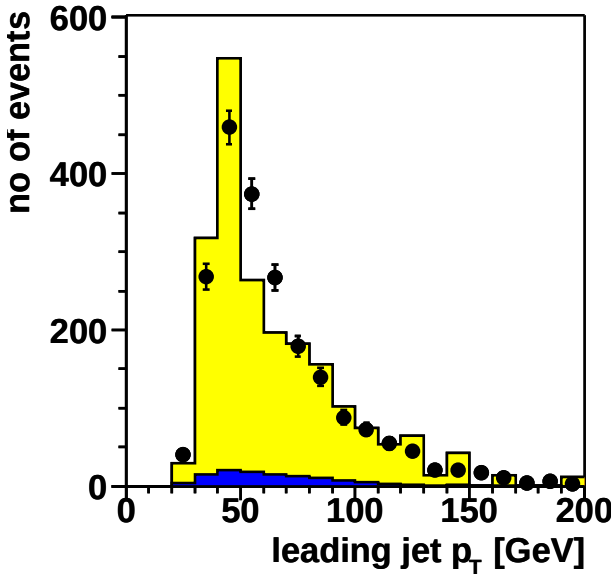
p_T cut

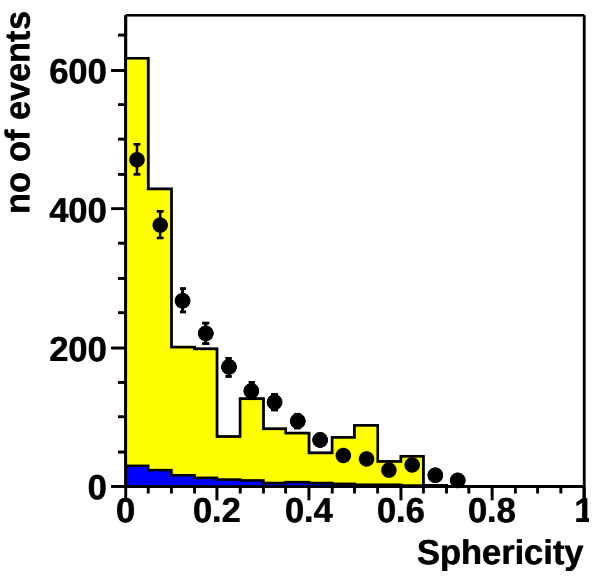


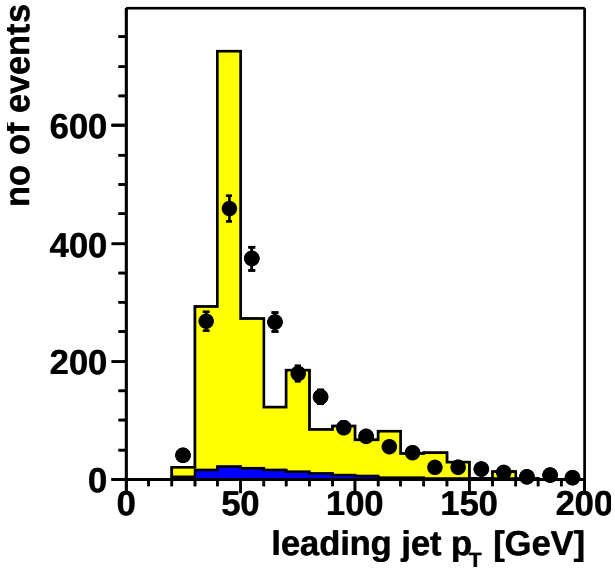
- $p_T > 10\,\text{GeV}$:
  better for p_T-spectrum.

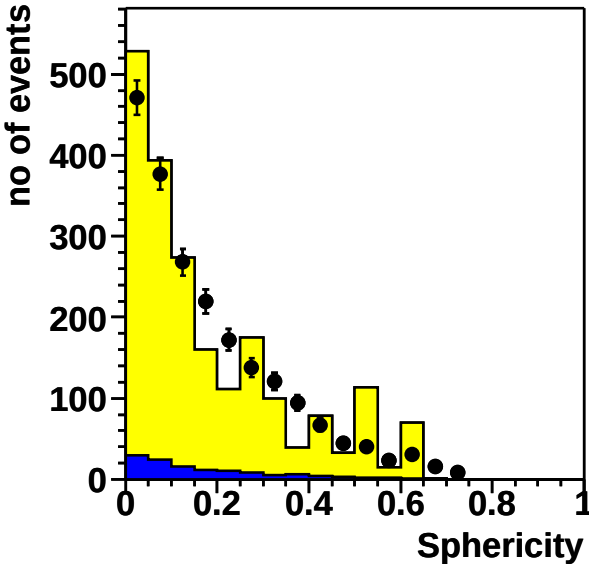
- $p_T > 30\,\text{GeV}$:
  (and also $p_T > 20\,\text{GeV}$)
  better in event shapes.

But our default unmatched samples look as good (maybe even better).







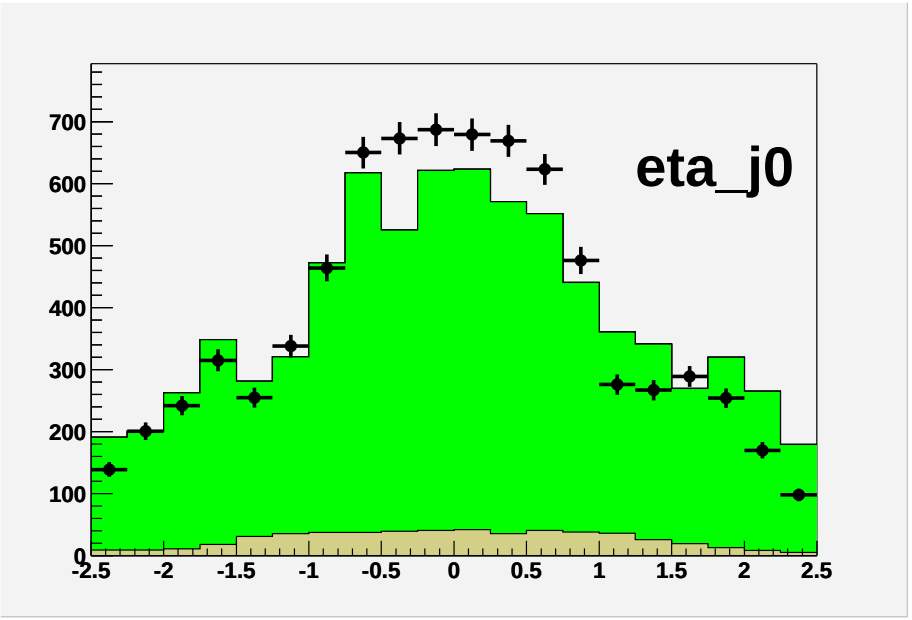


W+jets (Electron channel)

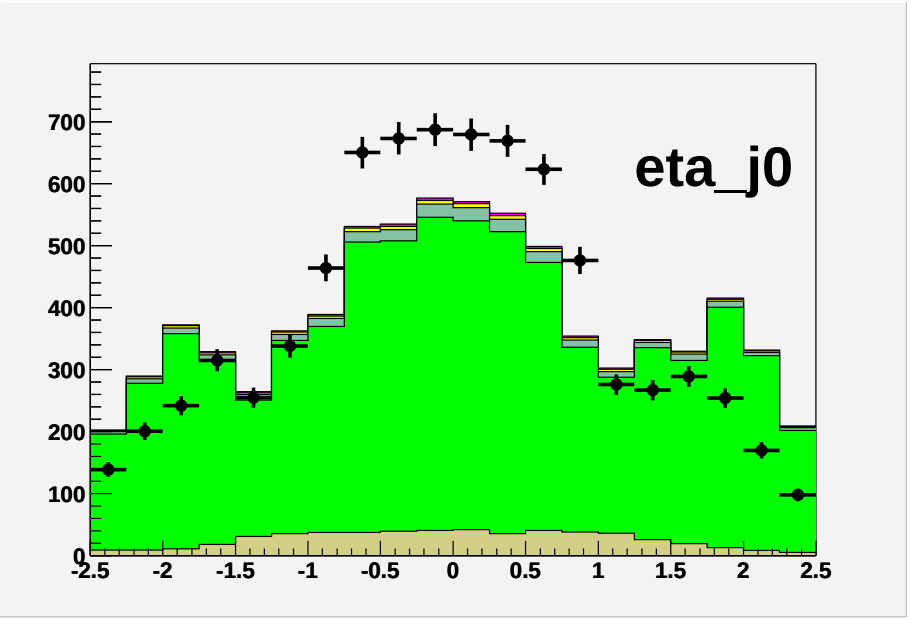
$t\bar{t}$ cross-section analysis in l+jets channel (with b-tagging).

Leading jet η distribution in $e + 1$jet

Unmatched



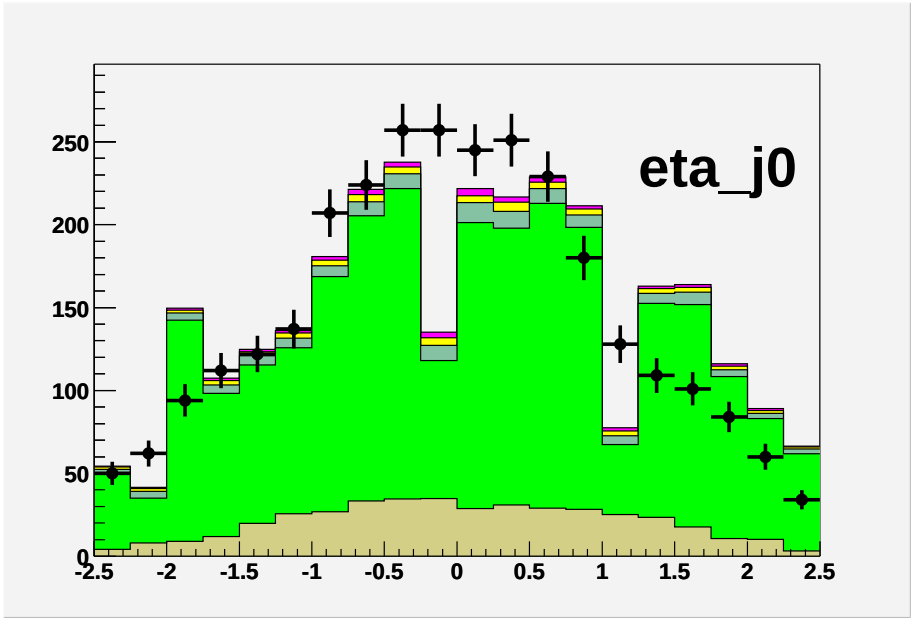
Matched



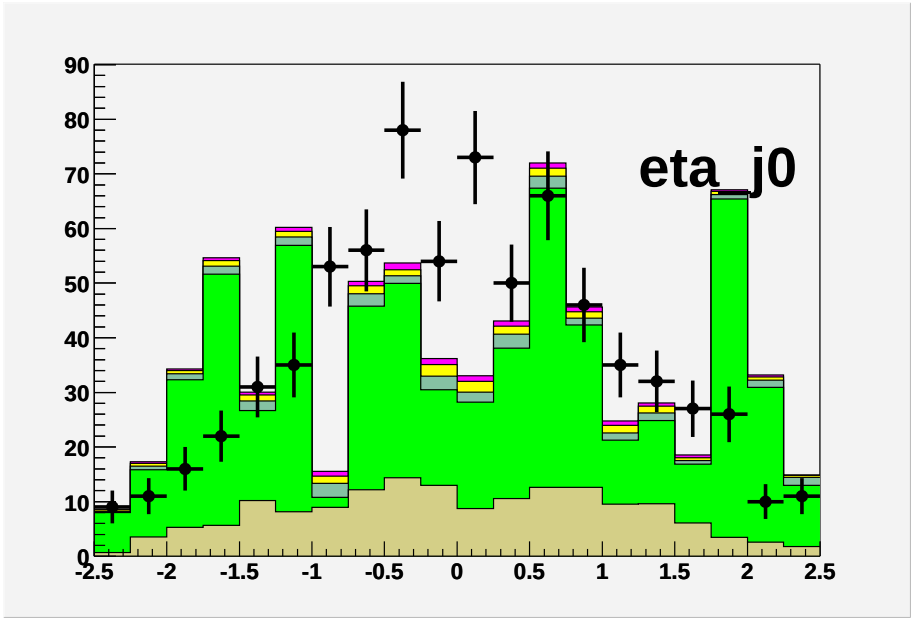
Discrepancy for the matched sample, . . .

Leading jet η distribution

$e + 2$jets



$e + 3$jets



. . . but higher jet multiplicities seem OK.

Z+jets (Muon channel)

Analysis Selection

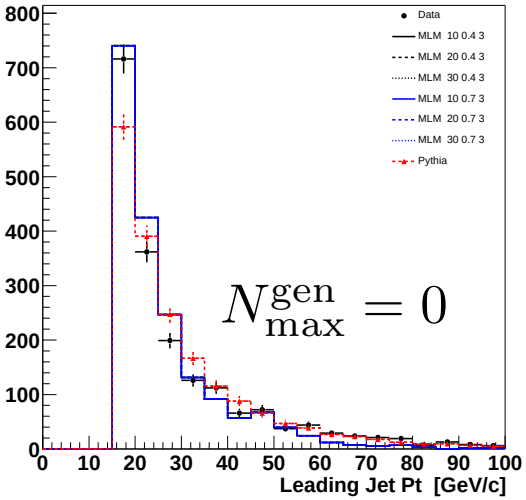
$t\bar{t}$ cross-section analysis in dimuon channel:

- Vertex quality
- 2 muons: Medium tagged, $p_T > 15\,\text{GeV}$, $\eta < |3|$.
- $75 < M_{\mu\mu} < 105\,\text{GeV}$

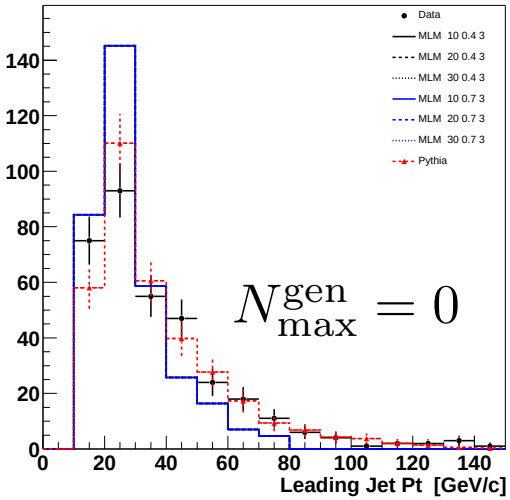
Investigating Z inclusive and $Z + 2$jet events.

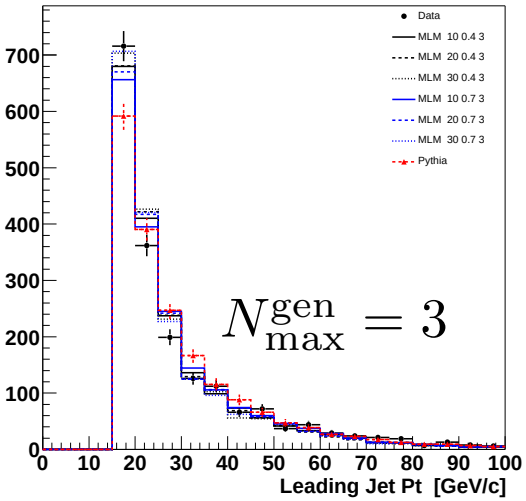
Leading jet p_T

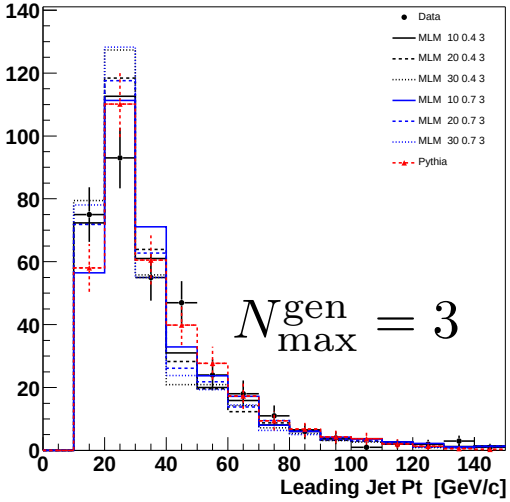
Z inclusive



$Z + 2$ jets





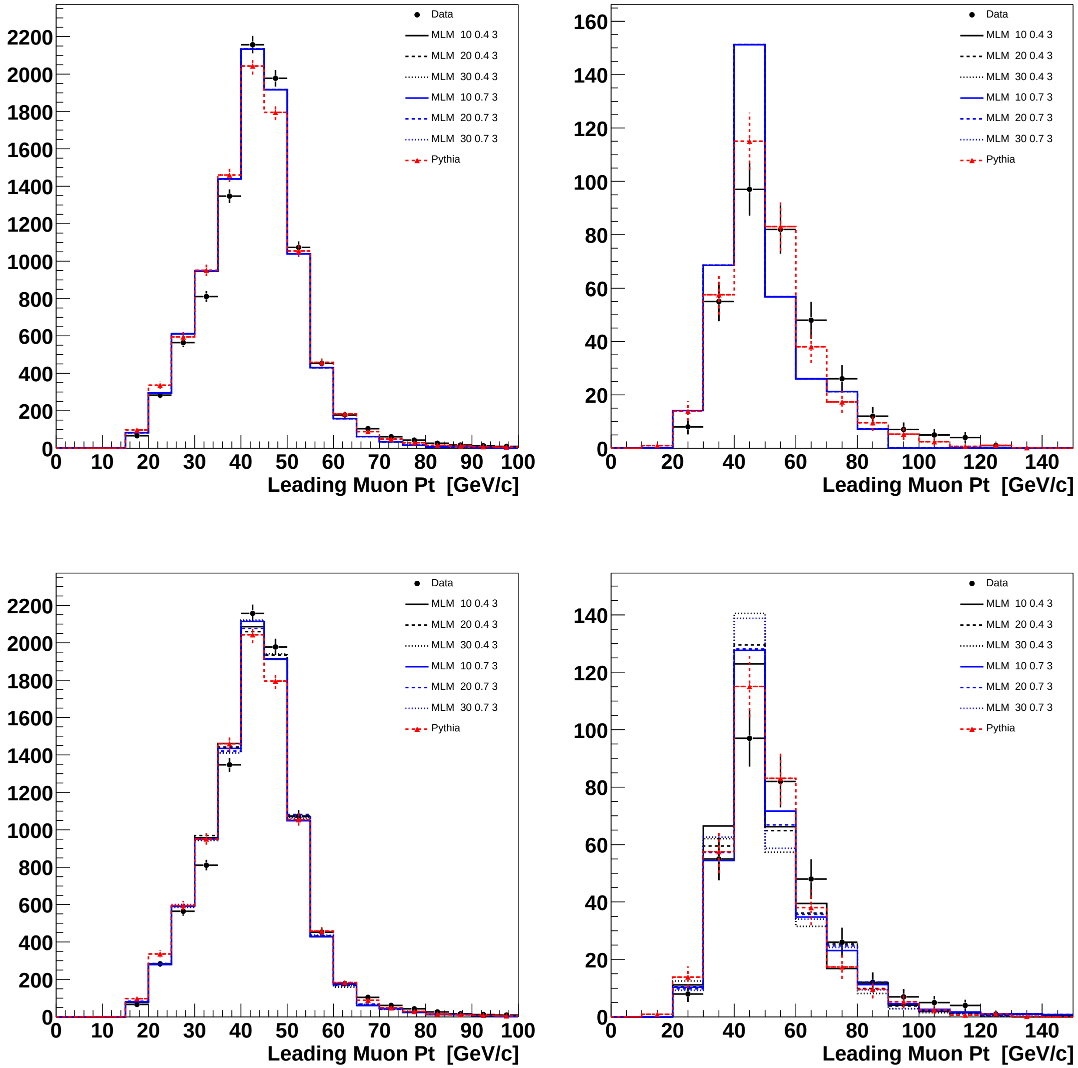


- Matched better in Z incl.
- But not in $Z + 2$j, here Pythia is wider data even more

– Matched Algen-Pythia
△ Pythia
• Data

Leading muon p_T

Z inclusive — $Z+2$ jets



- Matched better in Z incl.
- But not in $Z+2$j
  again matched too narrow

$N_{\max}^{\mathrm{gen}} = 0$

$N_{\max}^{\mathrm{gen}} = 3$

– Matched Algen-Pythia
△ Pythia
● Data

CKKW Matching

Introduction

The CKKW prescription restricts the PS such that double counting is avoided.

Implementations

F. Krauss and co. in Sherpa.

Steve Mrenna pre-produced samples using Madgraph II and Pythia.

Samples

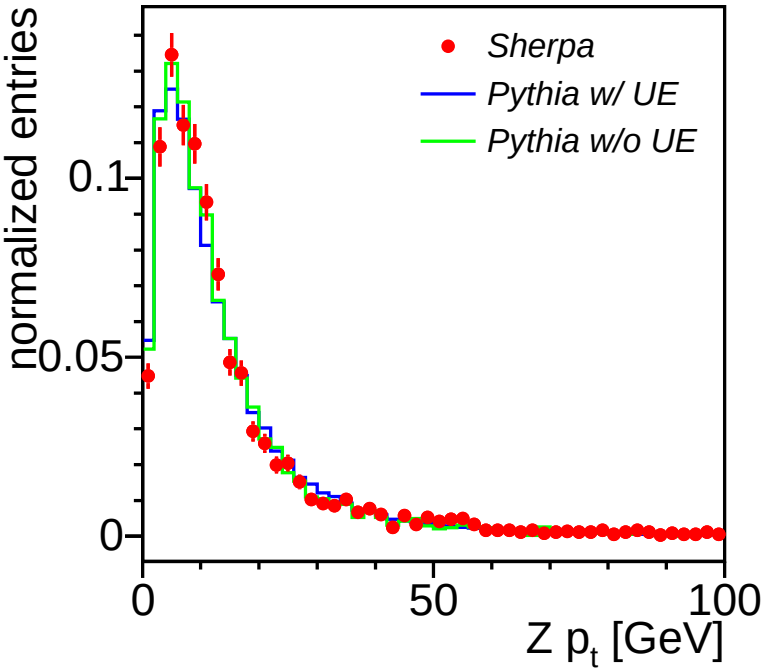
- Sherpa: Z+jets (ME up to $Z + 3\mathrm{j}$) with $Z \to \mu\mu$ and full det. simulation
- S. Mrenna samples are currently processed ....

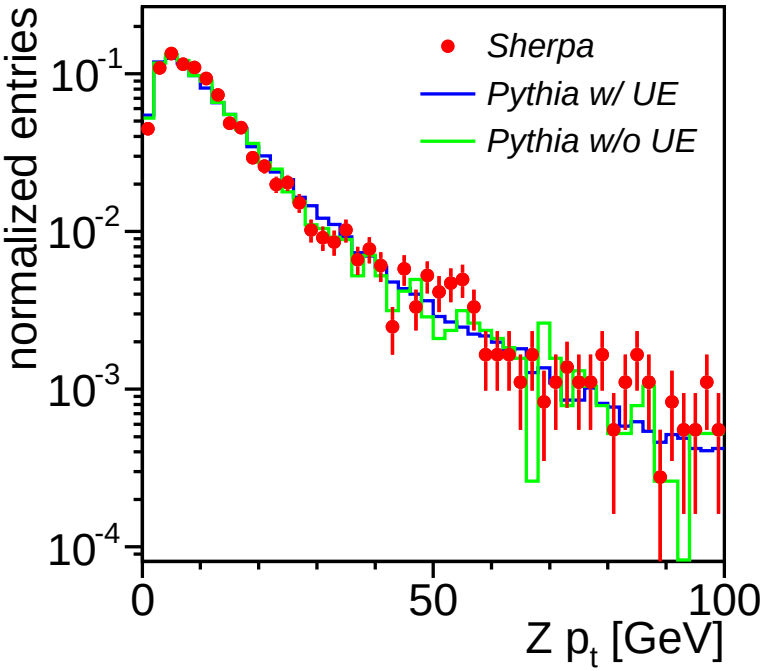
Z+jets

Sherpa compared to Pythia with and without underlying event.

$p_T(Z)$

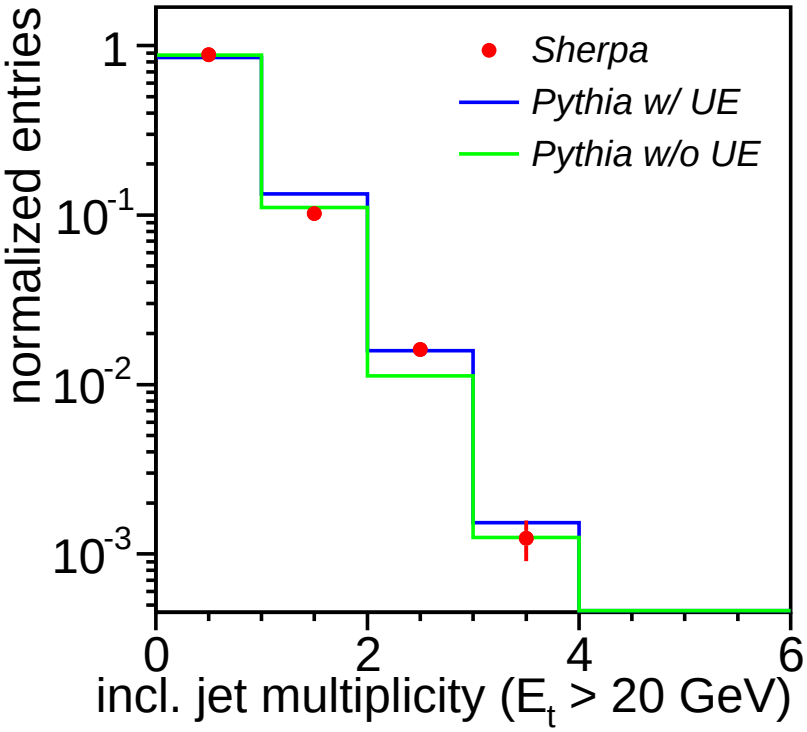
UE has not significant effect;
good agreement between models; but Pythia doesn't fully describe data.





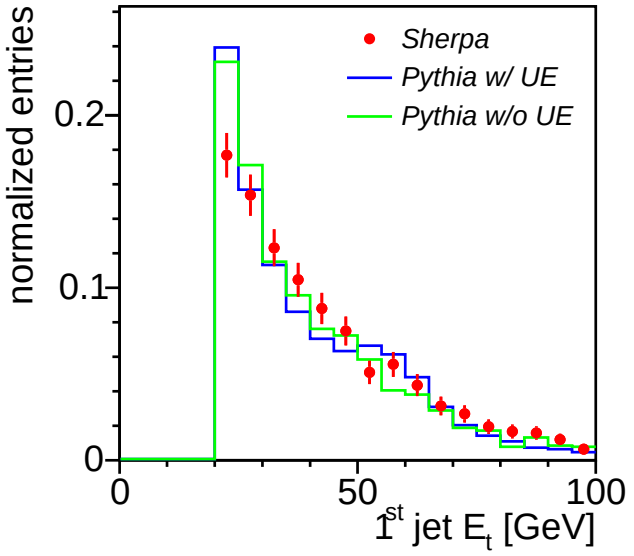
Jet multiplicity

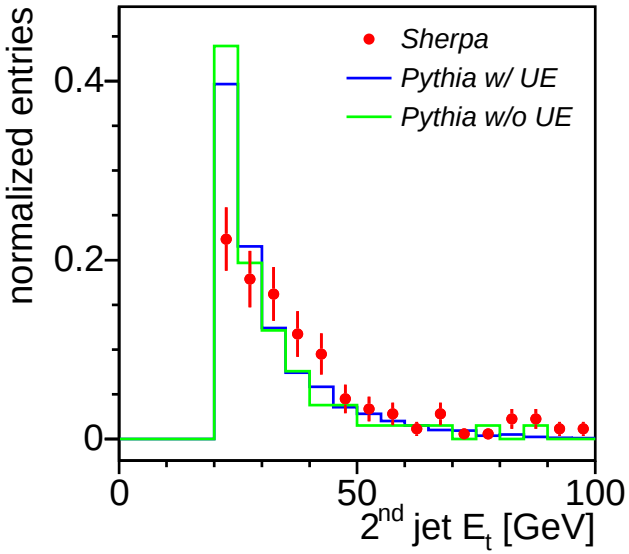
- Cone algorithm
  $\Delta R = 0.5$, $p_T > 20\,\text{GeV}$.
- UE increases jet multiplicity.
- Sherpa has more jets ($p_T > 20\,\text{GeV}$).

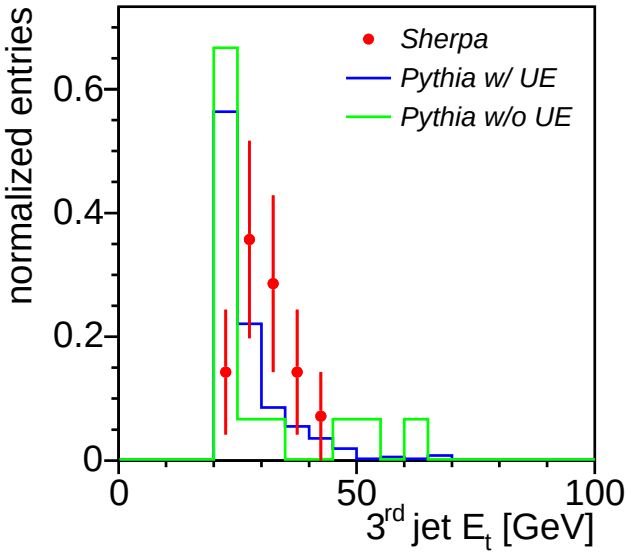


Leading jet p_T

- Small modifications due to UE.
- Sherpa shows harder spectrum.







Summary and Outlook

DØ has investigated MLM and CKKW matching schemes.

- MLM with Alpgen+Pythia and various prescription param. in Z+jets, W+jets.
  - (Tuned) pythia seems to be better in many cases.
  - Statistics isn't sufficient to be decisive (yet?).
  - Studies with heavy flavours are in progress.
- CKKW with Sherpa in Z+jets.
  - Underlying event model needed for fair comparison of Sherpa with data.
  - Expected in next version.
- CKKW with Madgraph+Herwig in progress.

Acknowledgments

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