Multi-jet final states: ALPGEN experience in CMS

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Disclaimer: this is not the foreseen presentation …

ALPGEN

- Getting the shapes right for njets final states → ALPGEN ME+matched PS for a number of channels, usually as a background study to Higgs or BSM searches
- Alpgen version 20x (mostly 205)
- Used parton shower matching CKKW with PYTHIA 6.25/6.35

Subrocess	Cross section (pb)	Events generated	Submitted to full sim
tt + 0 j (excl)	190	incoming	-
tt + 1 j (excl)	170	3259500	1400000
tt + 2 j (excl)	100	331500	331500
tt + 3 j (excl)	40	125000	125000
tt + 4 j (incl)	61	186000	186000

Example tt+njets

Process
W+Njets, N=0,1,2,3,4,5,6+
Z+Njets, N=0,..,6+
tt+Njets, N=0,1,2,3,4,5,6+
WW,WZ,ZZ+Njets, N=0,1,2,3,4+
Z/W bb + Njets, N=0,1,2,3,4+
bb+Njets, N=0,1,2,3,4,5,6+
bbbb +Njets, N=0,1,2,3,4+
gamma+Njets, N=1,...,6+
Njets, N=2,3,4,5,6+
gamma gamma + Njets, N=0,..,6+
WWW,WZW,ZWZ,ZZZ + Njets, N=0,1,2,3+
Z+Mc+Njets, M=2, N=0,1,2+
t + Njets, N=0,1,2+

ALPGEN: Procedure

- Interactive [preparatory for large scale production]
  - Build stable phase space .grid2
    - For subsequent use in same process larger scale production
  - Generate weighted,unweighted,matched events to extract:
    - Overall efficiency
    - Number of input events required for a requested yield of generated events [corresponding to X fb^{-1}]
    - CPU per jet multiplicity bin
- On the Grid, [large scale production]
  - Use stable phase space .grid2
  - Generate weighted,unweighted,matched events
  - Retrieve results in form of .tgz and store in castor
  - Stage the archives on disk/Uncompress and extract the final file

efficiencies	before matching (p_T>20 GeV)	Parton shower matching
0 jets	4%	80%
6 jets	3.10^{-5}	6%

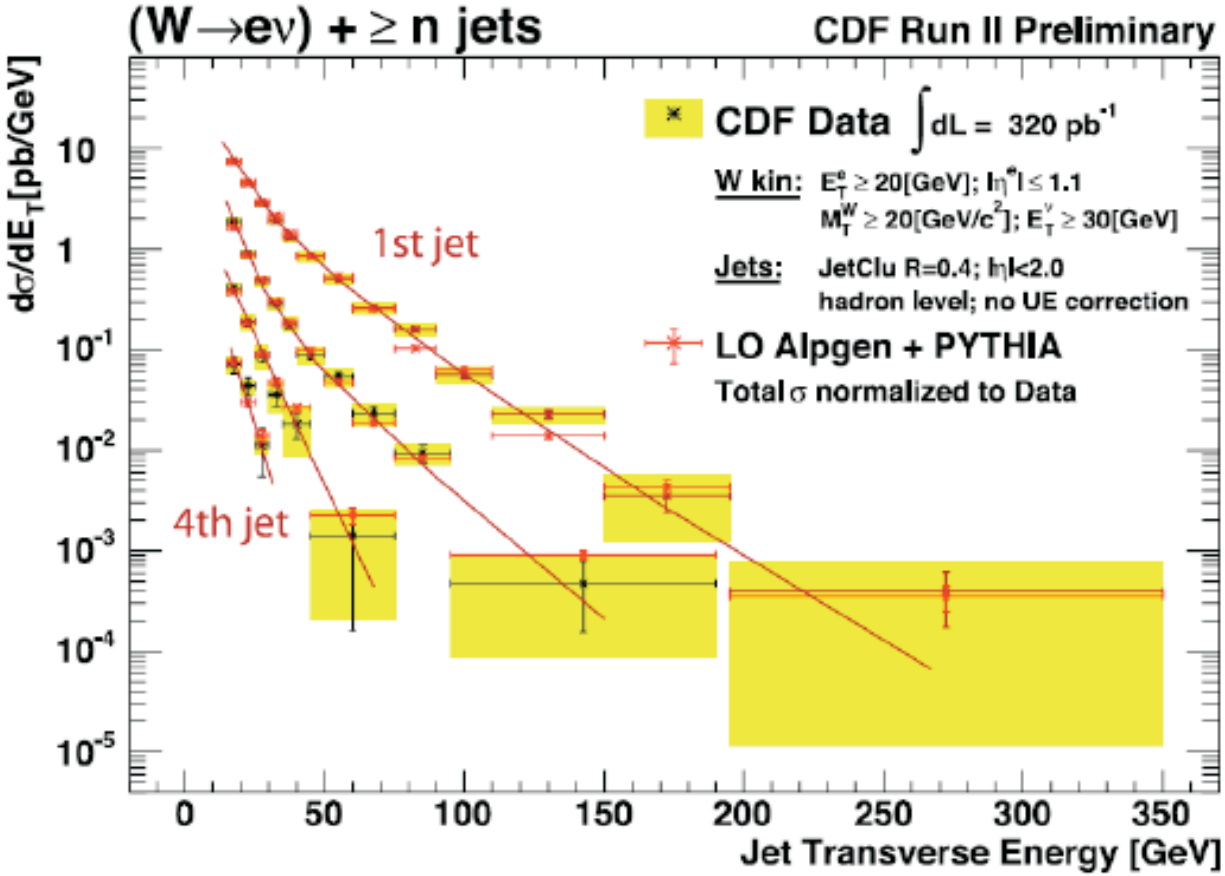
ALPGEN

- Mass production more tedious than wanted/lot of book keeping and computing resources needed
  - Unstable PS grids
    - Empirical solution: increase iterations and numbers of events to form stable grid2 as a function of jet bin
  - CPU (abortions/crashes for large Nj)
    - Empirical solution: decrease number of requested events as a function of jet bin
  - Disk space (staging the archives)
- Used cross section normalization procedure
  - Normalize each sample to the matched cross section
  - Add all samples
  - Normalize total sample to NLO cross section (e.g. from MCFM)
  - Care on the generator level requirements
  - Procedure needs to be thoroughly tested

Normalization procedure

Annecy 06

- How to normalise MC event generators especially in multi-leg hadronic final states (many jets beyond MC@NLO). Establish control sample of data for overall normalisation? Extrapolation to other final states/data sets possible ?



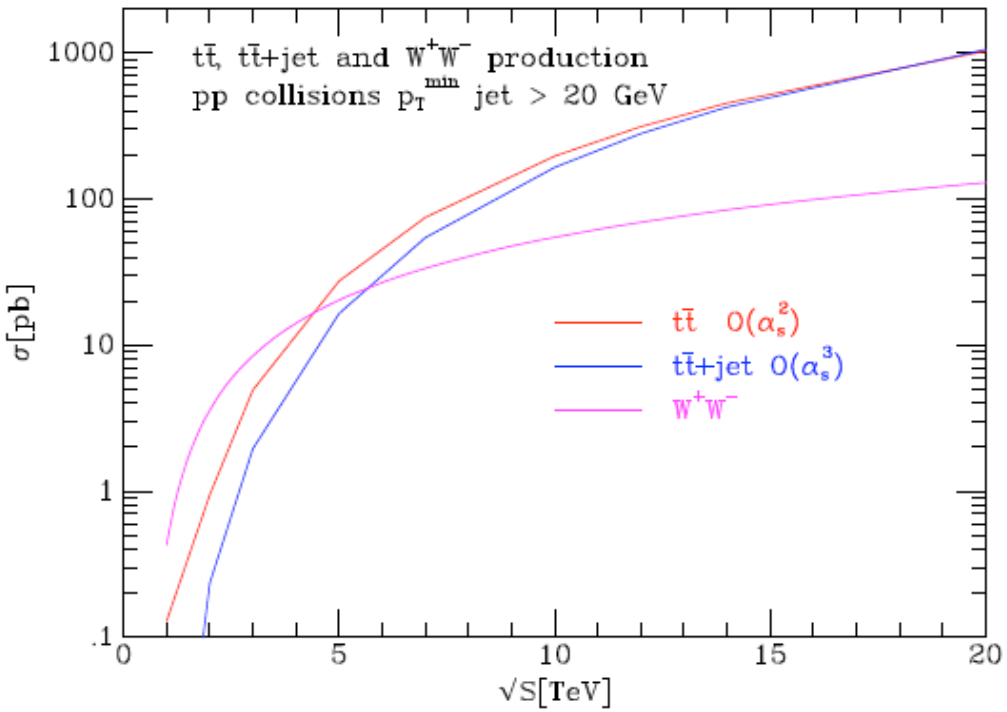
Normalize to data or to NLO total cross section?

Discussion Tuesday AM

Top, W, Z+ njet Production Normalization

Will be essential to understand properly for BSM searches: Eg Top

Top +jet production at LHC



MCFM prediction

K. Ellis

How to normalize tt+2jet or tt+3 jet?

- $t\bar{t}$+jet cross section same as $t\bar{t}$ cross section; Radiation probability is one.
- Note that a $p_T = 20$ GeV jet can be adequately described using the soft approximation.
- The W^+W^- cross section is also shown, (subject to gauge cancellation)

Example: QCD Njets ALPGEN

ALPGEN v201 $Q^2 = \Sigma P_T^2(\text{parton})$ PDFs CTEQ5L

Matching scheme CKKW (M Mangano impementation in Alpgen, see *http://mlm.home.cern.ch/mlm/alpgen)*- Interface with PYTHIA 6.227

Jet parameters for matching:

$E_T(\text{jet}) > 15$ GeV

R(jet) = 0.525,

$\Delta R(\text{parton-jet}) < 0.7875$

samples

2-to-2 : $N_{partons}=2$; $P_T(\text{parton})>20$ (100) GeV; letal<5
$\Delta R(\text{parton-parton}) > 0.7$

2-to-3 : $N_{partons}=3$; $P_T(\text{parton})>20$ (100) GeV; letal<5
$\Delta R(\text{parton-parton}) > 0.7$

2-to-4 : $N_{partons}=4$; $P_T(\text{parton})>20$ (100) GeV; letal<5
$\Delta R(\text{parton-parton}) > 0.7$

samples cross sections

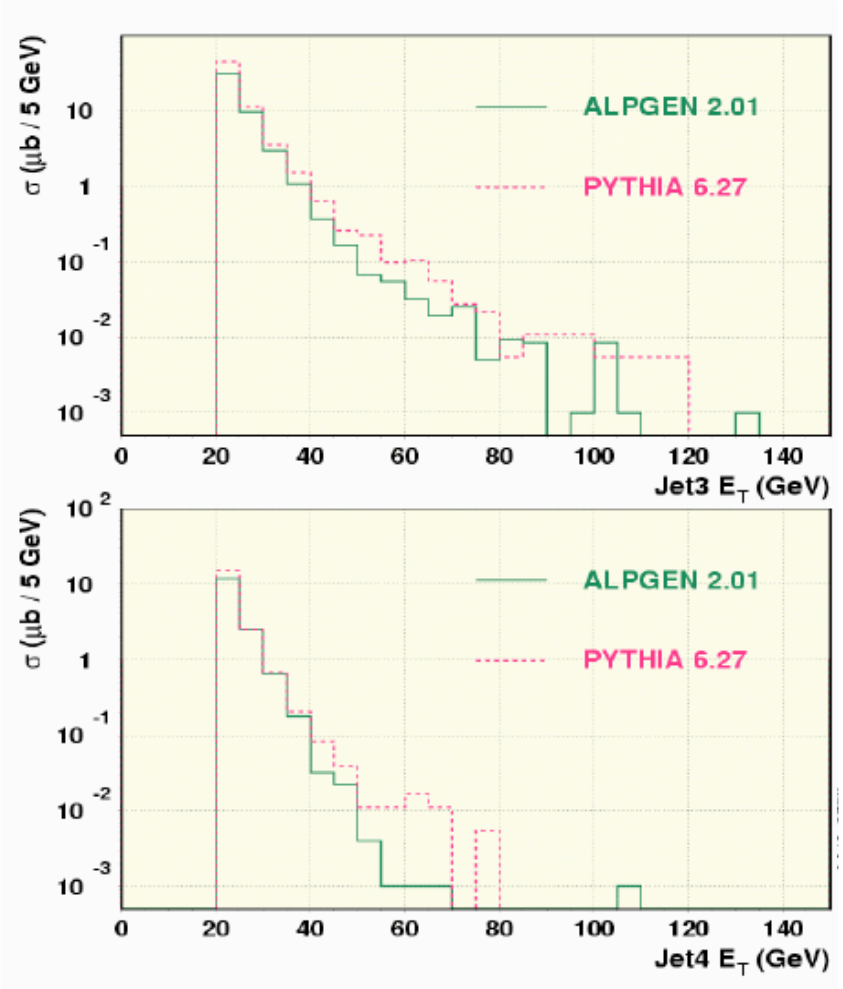
20 GeV

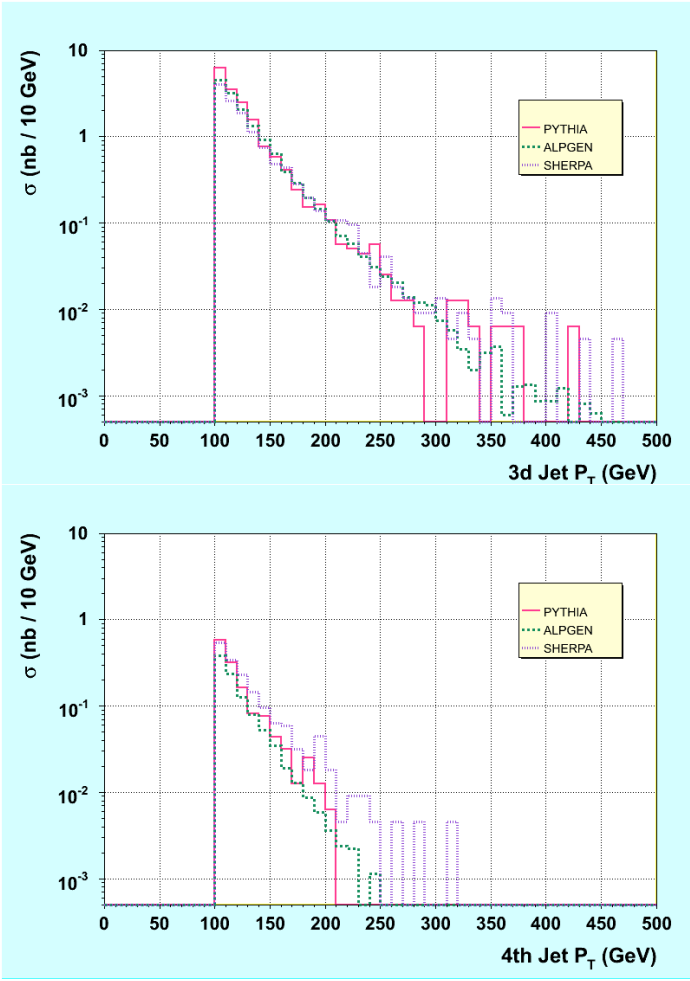
sample	σ(matched-alp)	σ(unw-alp)	matching ε	σ(pythia)
2-2	0.4 mb	0.8 mb	0.5	-
2-3	0.02 mb	0.06 mb	0.3	-
2-4	0.0024 mb	0.016 mb	0.15	-
total	0.45 mb	0.876 mb	-	0.83 mb

100 GeV

sample	σ(matched-alp)	σ(unw-alp)	matching ε	σ(pythia)
2-2	6×10^{-4} mb	0.0013 mb	0.45	-
2-3	1.5×10^{-5} mb	4×10^{-5} mb	0.38	-
2-4	1×10^{-6} mb	3.6×10^{-6} mb	0.27	-
total	6.16×10^{-4} mb	1.344×10^{-3} mb	-	6.3×10^{-4} mb

QCD Njets ALPGEN





Low p_T range and up to 4 jets: No big difference observed

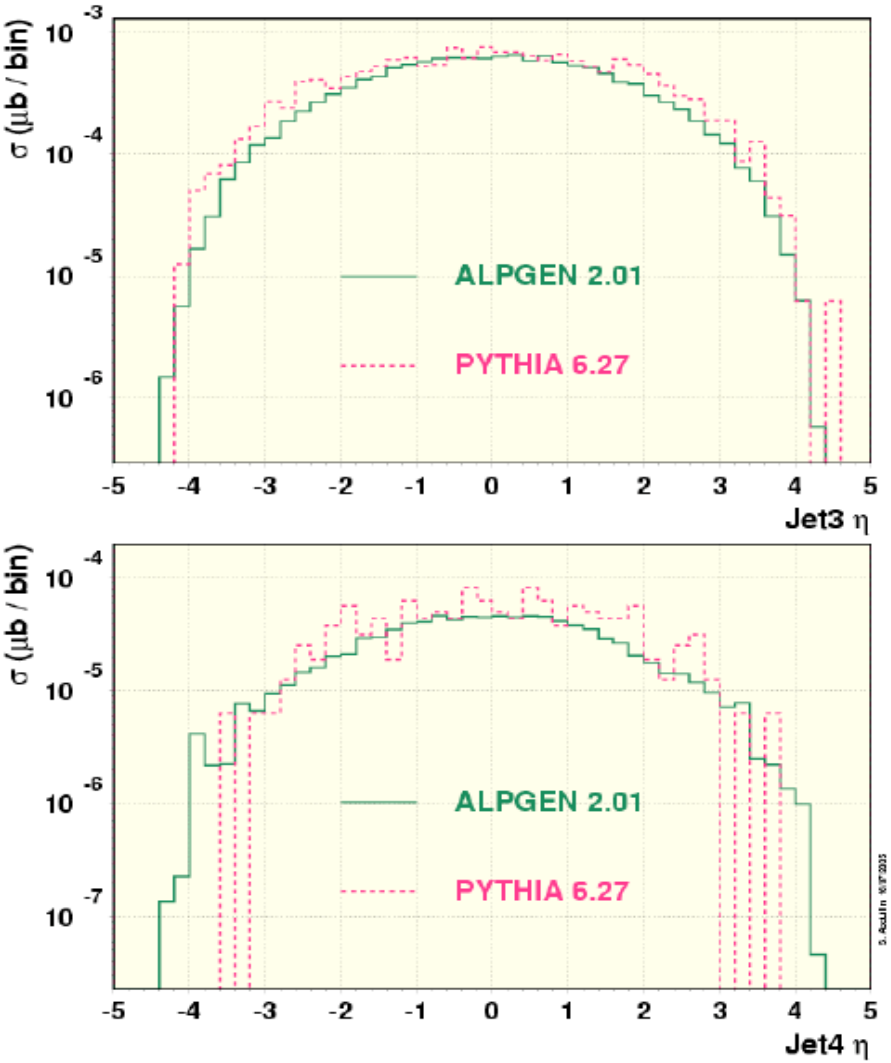
Effects of ALPGEN expected at high jet multiplicities and high parton p_T

QCD Njets ALPGEN

Pseudorapidity distributions

3d jet $E_T > 100$ GeV,
4^{th} jet $E_T > 100$ GeV

Note: Systematics from matching in progress !
Determine Inclusive/Exclusive usefulness (i.e: stop at 4 jets and tune the matching such that the 5th, 6th jets are predicted correctly?)



Similar observations for W,Z,tt+jets, see talk tomorrow morning

Summary

- Primary concern now is to get ready for the LHC startup (2007) 2008
  - Jets, W-Z-t(t)+ njets, WW-ZZ+njets,W-Zbb,ttbb,Wγ,Zγ, min bias…
- A number of questions raised
  - Which are the generators to be used? Model versions, parameters …
  - PDFs NLO PDFs for LO MCs?
  - QCD in the new LHC kinematic regime? Special generators?
  - How to normalize the MCs

Backup

Requirements: tools and calculations

- Les Houches 05: What are the real uncertainty bands (from higher orders,scale uncertainties, PDFs). This has not yet been done even for some simple cases!

  We will obviously try to use our own data as much as possible (sidebands, independent measurements) but tuned Monte Carlos will play an important role in the analysis. Hence Standard Model processes will be important particulalry W,Z + jets, tt +jets , bb + jets, n-jets…

  ⇒ Calculations and generators; NLO, NNLO; ME+PS matching
- Upgrade MC@NLO for
  - WW, WZ with spin correlations, DY, W+jets
- MC@NLO+PYTHIA
- Event generator including EW effects
- Event generator based on Ariadne QCD treatement
- PYTHIA6.3 tuned version
- Underlying event/minimum bias event decriptions
- Toolkits for SM and BSM processes (via LH-accords)

QCD predictions: ALPGEN vs Data

QCD Multijets in D0

# jets	cuts	reference exp.	cross section exp. / pb	cross section theory / pb
3	A	[10]	38300 ± 200 (stat)	35000 ± 800 (stat)
3	B	[7]	6.7 ± 0.3 (stat)	16 ± 10 (stat)
4	A	[10]	6750 ± 75 (stat)	4500 ± 200 (stat)
6	C	[8]	48 ± 1 (stat)	89^{+25}_{-15} (stat)

Table 2: Comparison of measured and calculated (Alpgen+Pythia) multijet cross sections.

A	$E_T > 20\,\text{GeV}, E_\perp(1st\ jet) > 60\,\text{GeV}, \lvert\eta\rvert < 3, m > 200\,\text{GeV}, R_{ij} > 1.4$
B	$E_T > 20\,\text{GeV}, \lvert\eta\rvert < 3, \sum_j E_\perp > 420\,\text{GeV}, m > 600\,\text{GeV}$
C	$E_T > 20\,\text{GeV}, \lvert\eta\rvert < 3, \sum_j E_\perp > 320\,\text{GeV}$

Table 3: Cuts used for multijet event selection

ME+PS Matching

Important topic:
Simulate both structure of jets and many high Pt jets

CKKWV (Catani-Krauss-Kuhn-Webber) prescription/now being implemented in HERWIG

The way to go?

Q: if LHC at startup sees a number of 8,9,10 jets events, how well do we the prediction…