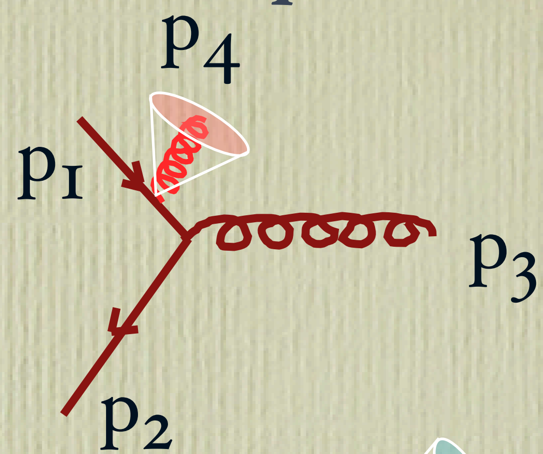
A review of MLM's prescription for removal of double counting

Michelangelo Mangano, CERN TH

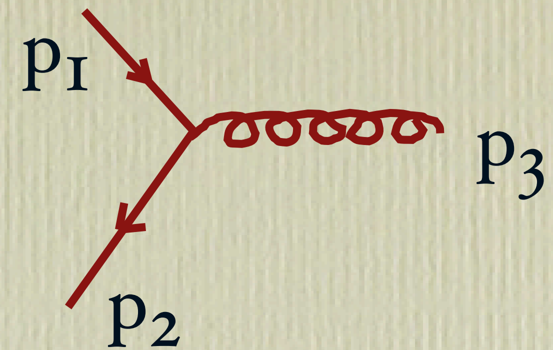
MC4Run2, FNAL, June 11 2004

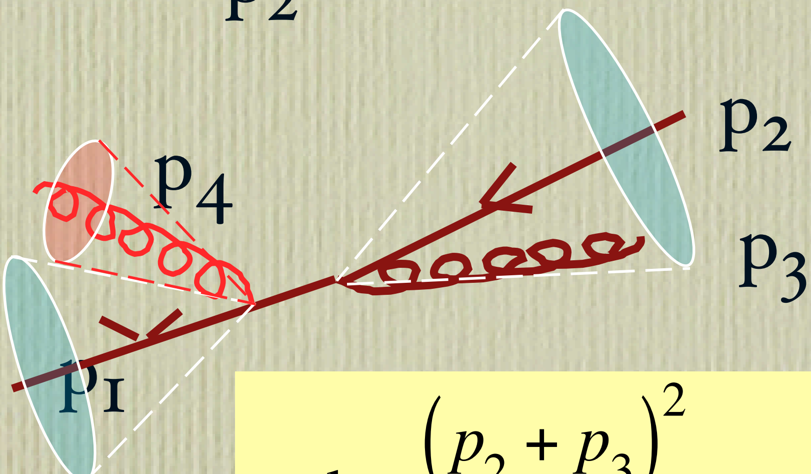
- Goals of this prescription:
  - to eliminate the dependence of physical cross-section on the cuts used at the generator level (original goal, see my Fall 2002 talk, http://cepa.fnal.gov/patriot/mc4run2/MCTuning/15nov2002.html)
  - to eliminate the double counting of configurations where jets can arise from both the higher-order PL calculation, and from the hard emission during the shower evolution
  - to provide a recipe to construct inclusive event samples describing arbitrary jet multiplicities, free of double-counting (á la CKKW)

The problem of Leading-log-order double counting



is of $O(\alpha_s)$ relative to the LO process

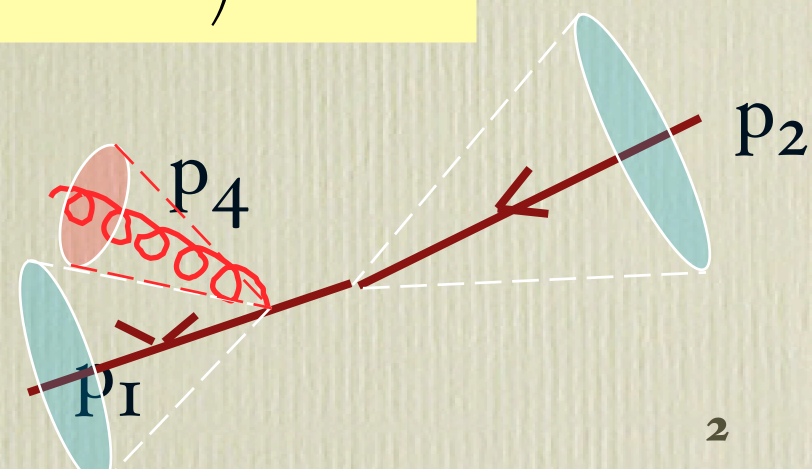




instead gives a contribution to $\sigma_{3\text{-jet}}$ of order

$$\alpha_s \log \frac{(p_2 + p_3)^2}{E_{T\ jet}^2} \approx \alpha_s \left(\log \frac{p_T^{\max}}{p_T^{\min}} + \log \frac{1}{\Delta R} \right) \approx O(1)$$

Double counting, since this configuration is already generated by showering:



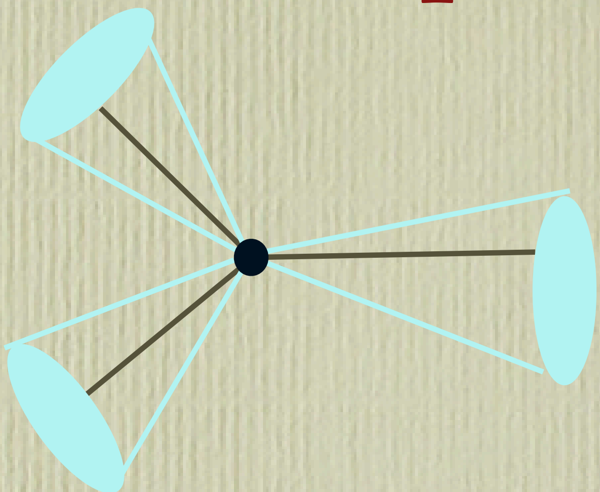
A simple prescription to address this problem

- **Generate parton-level configurations** for a given hard-parton multiplicity N_{part}, with partons constrained by
  - $p_T > p_{T\,min}$ $\quad \Delta R_{jj} > R_{min}$
- **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**

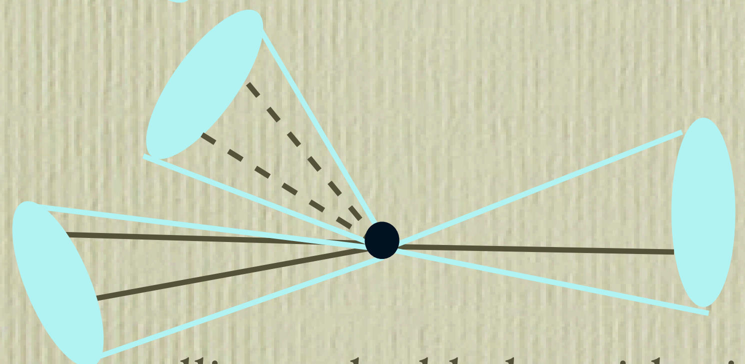
Few examples:

——— hard parton

- - - - - parton emitted by the shower



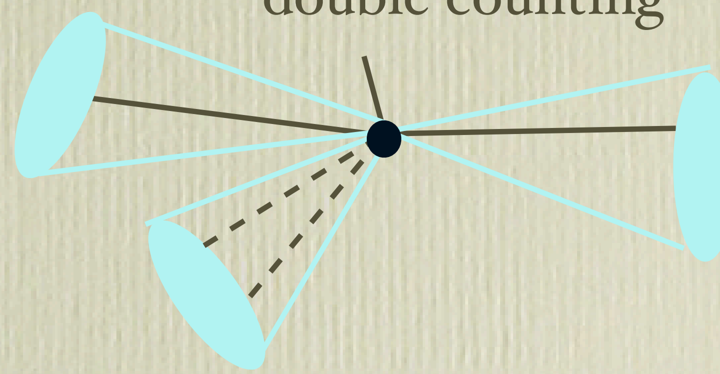
Event matched, N_{jet}=N_{part}=3, keep

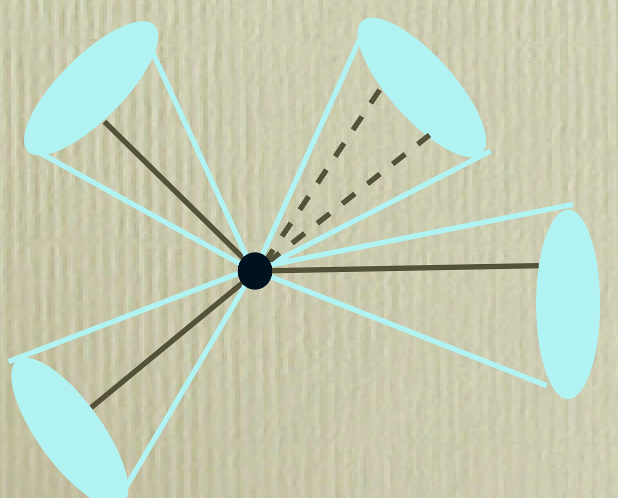


collinear double-logarithmic double counting

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

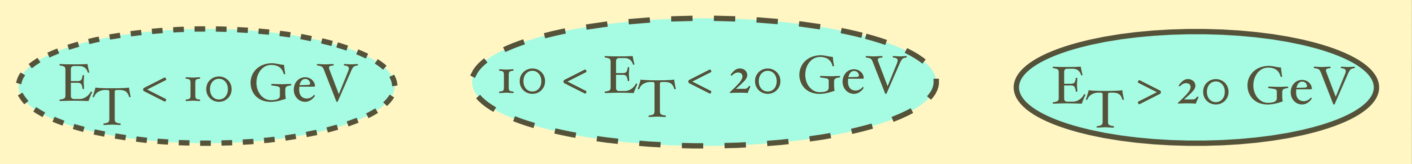
soft single-logarithmic double counting





Event matched, N_{jet}>N_{part}, keep for inclusive sample, but throw away for exclusive samples.

EXAMPLE



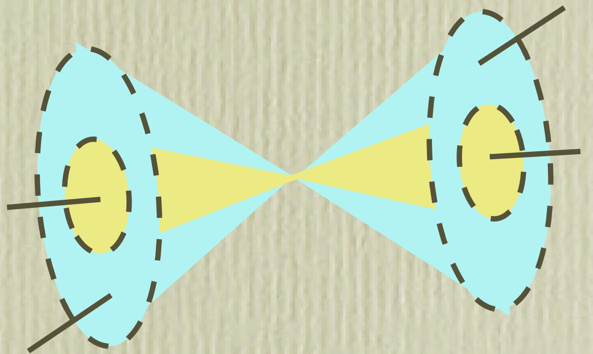
1) Select exclusive samples using matching with [20,0.7]

2) Use these samples to generate events with [10,0.4] jets.

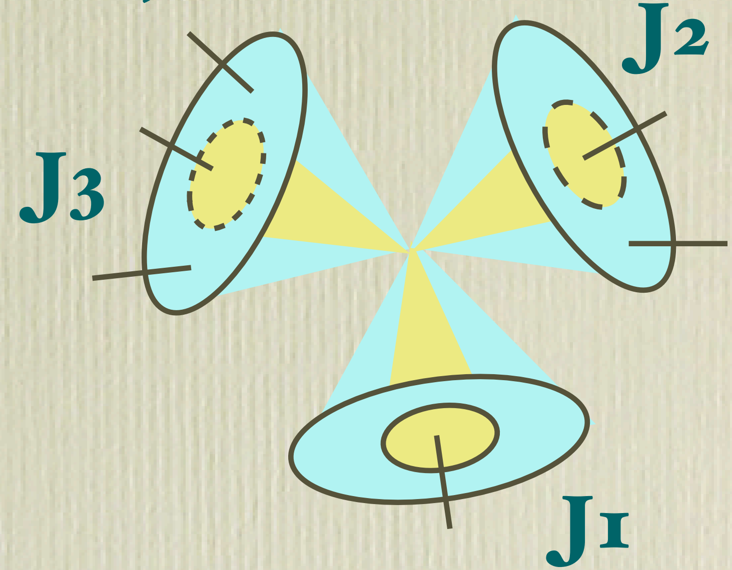
Where do the events with E_T<20 come from?

3) Take e.g. $N_{jet}^{[10,0.4]}$ = 2. In addition to events from $N_{jet}^{[20,0.7]}$=2, this contains as well:

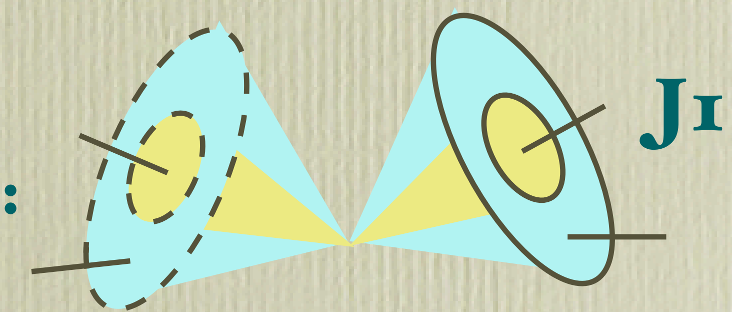
$N_{jet}^{[20,0.7]}$ = 0:



$N_{jet}^{[20,0.7]}$ = 3:



$N_{jet}^{[20,0.7]}$ = 1:

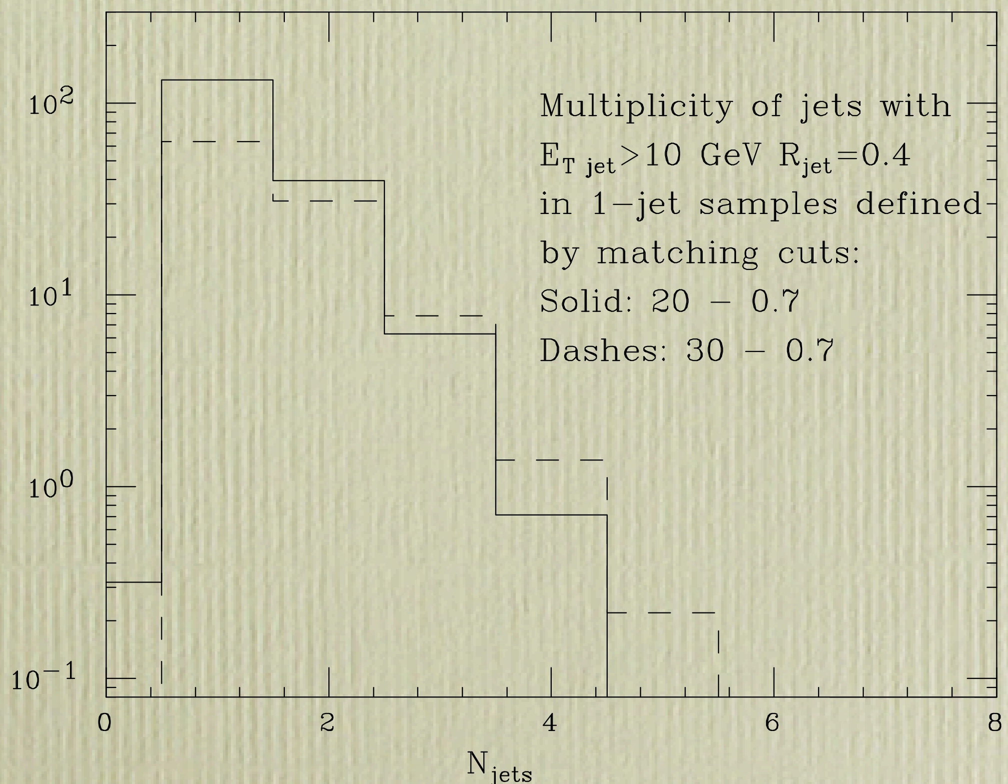


For $N_{jet}^{[20,0.7]}$=0 (1), this implies relying on the MC approximation for the emission of **two** (**one**) jets. This is not necessarily bad, since the phase space for 10< $E_{T\{1,2\}}$ <20 is very small anyway!

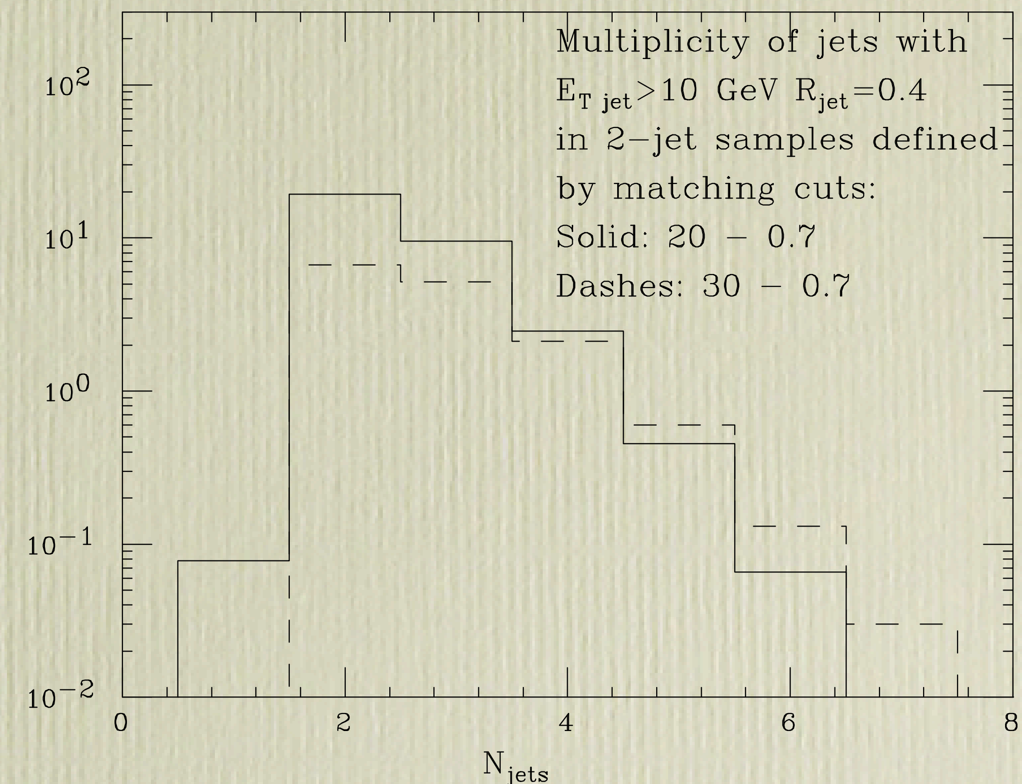
Comments

- The rejection of events with $N_{jets}>N_{parton}$ is equivalent to the Sudakov reweighting of CKKW. Instead of rejection on the basis of reweighting, rejection here takes place as a result of final-state topology. CPU-wise, the efficiency is comparable.
- The choice of a cone algorithm is arbitrary: the clustering algorithm is just a topological criterion to classify events and ensure the **absence of double counting** (this is guaranteed by the algorithm)
- The definition of generation cuts, and of jet cuts after the shower, are required as operative options to generate the sample, but **the physics obtained from the inclusive sample should not depend on them**. The inclusive sample so obtained can be used for any analysis, where possibly different jet definitions will be employed
- The extent to which results depend of the initial generation cuts is a measure of the success of the matching prescription
- Not necessary that $E_{T\,min} = p_{T\,min}$ or $R_{min} = R_{jet}$: the matching condition ensures limited dependence on this choice.

Concrete example:
W+jets, multiplicity distributions for {10.0.4} jets reconstructed in of exclusive 1- and 2-jet samples defined by matching at {20,0.7} and {30,0.7}



$N_{matched\ jet}=1$



$N_{matched\ jet}=2$

Some examples: W+multijets

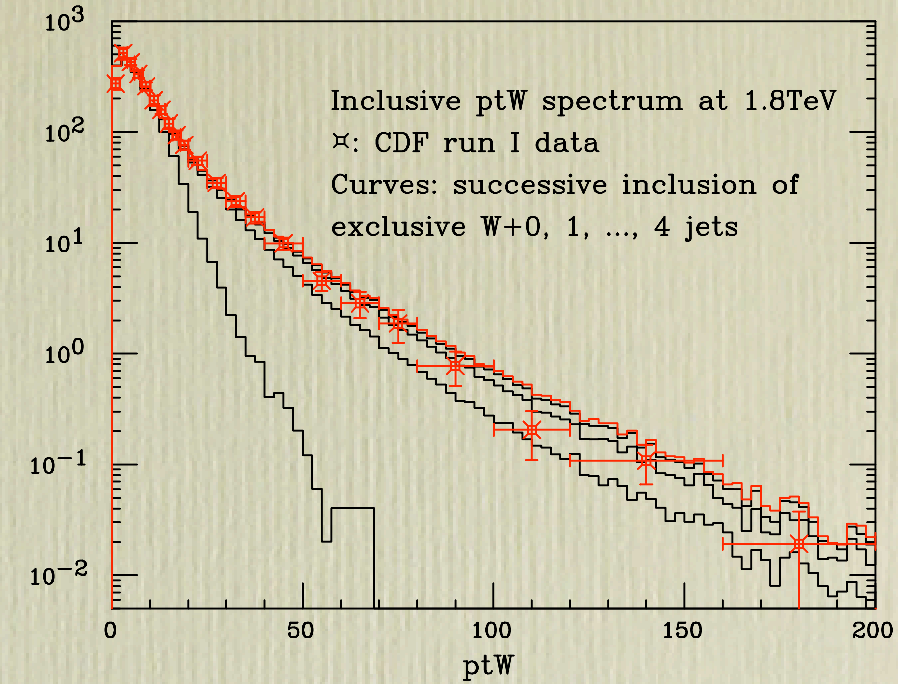
Define parton-level samples using

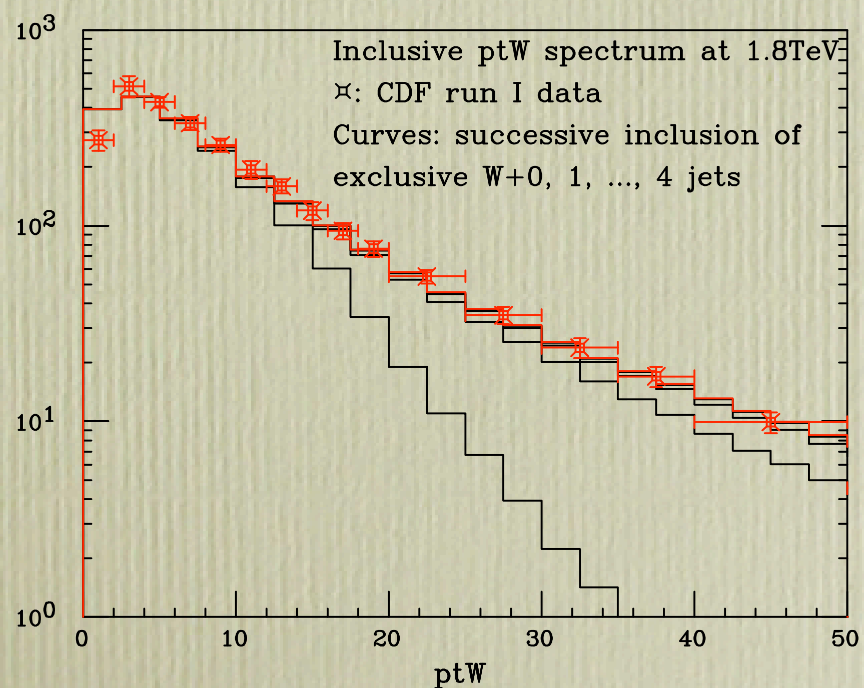
p_{Tmin} = 10, 20, or 30 GeV (PT10, PT20, PT30)

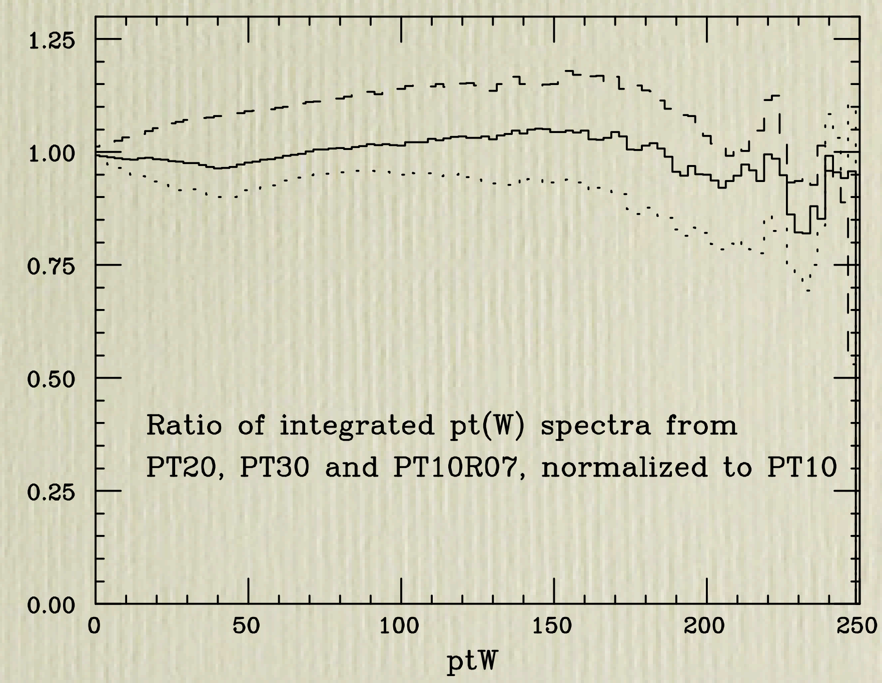
R_{jj}=0.4 or 0.7 (PT10R07)

Shower and reconstruct jets using R_{cone}=0.4

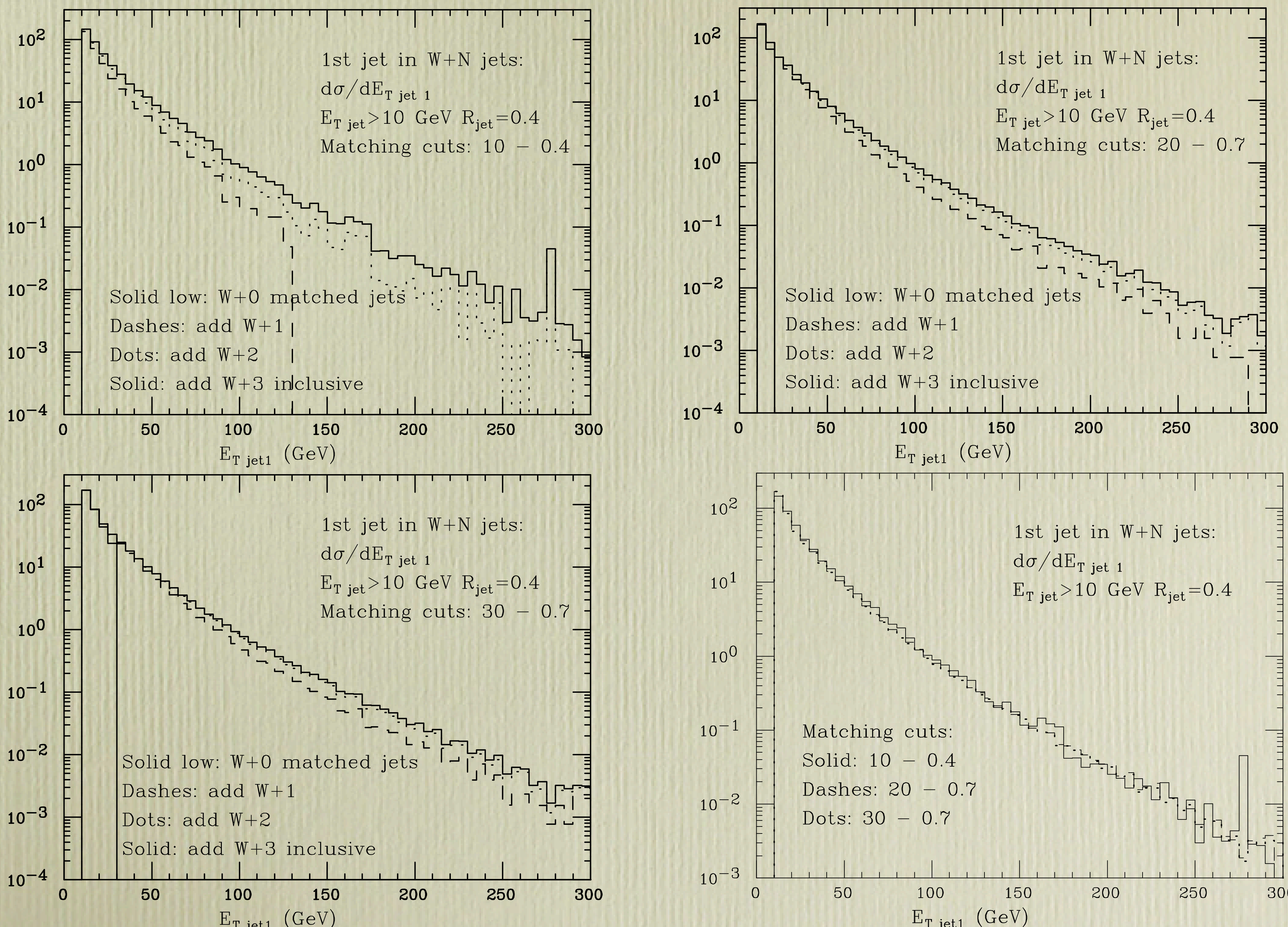
Study dependence of inclusive W and inclusive jet spectra on generation parameters



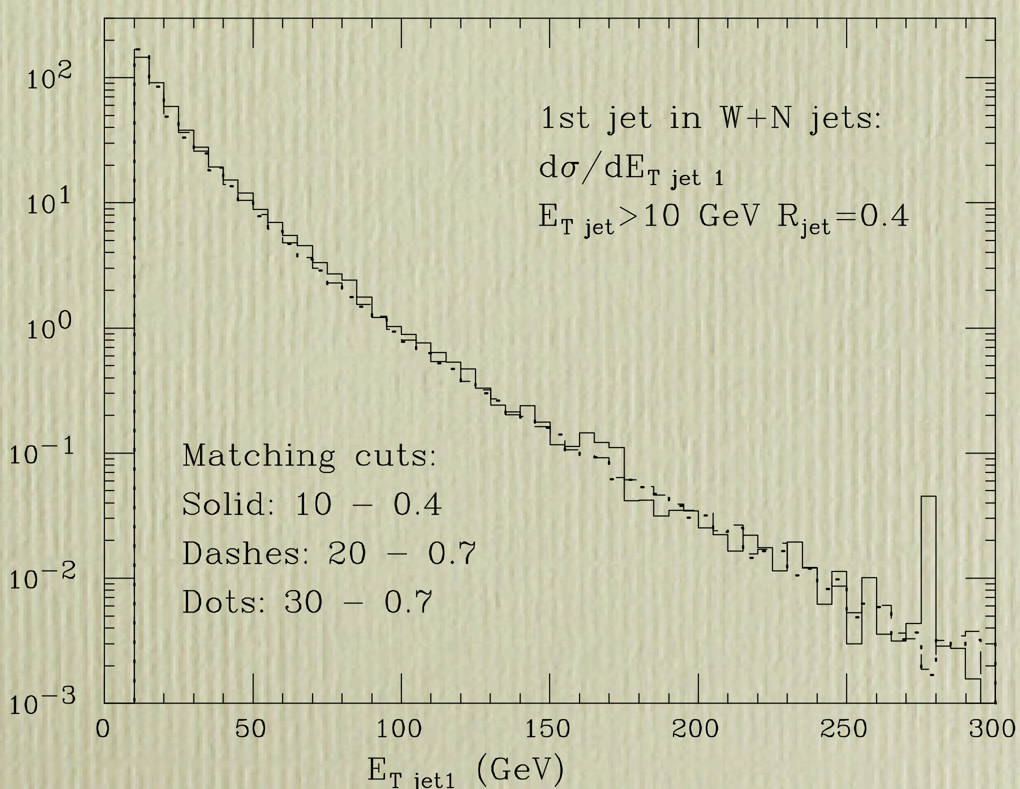




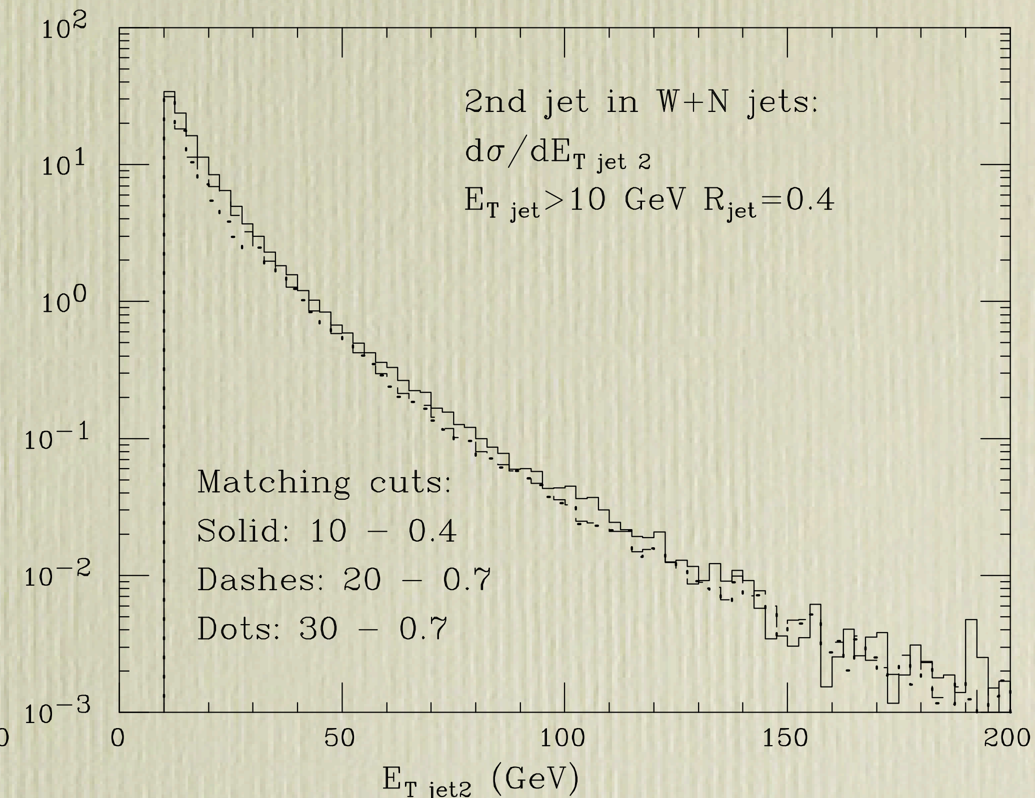
Leading-jet[10,0.4] Et distribution: multijet composition with different matchings



Comparison of resulting spectra for leading and second-leading jet in inclusive samples defined by different matchings

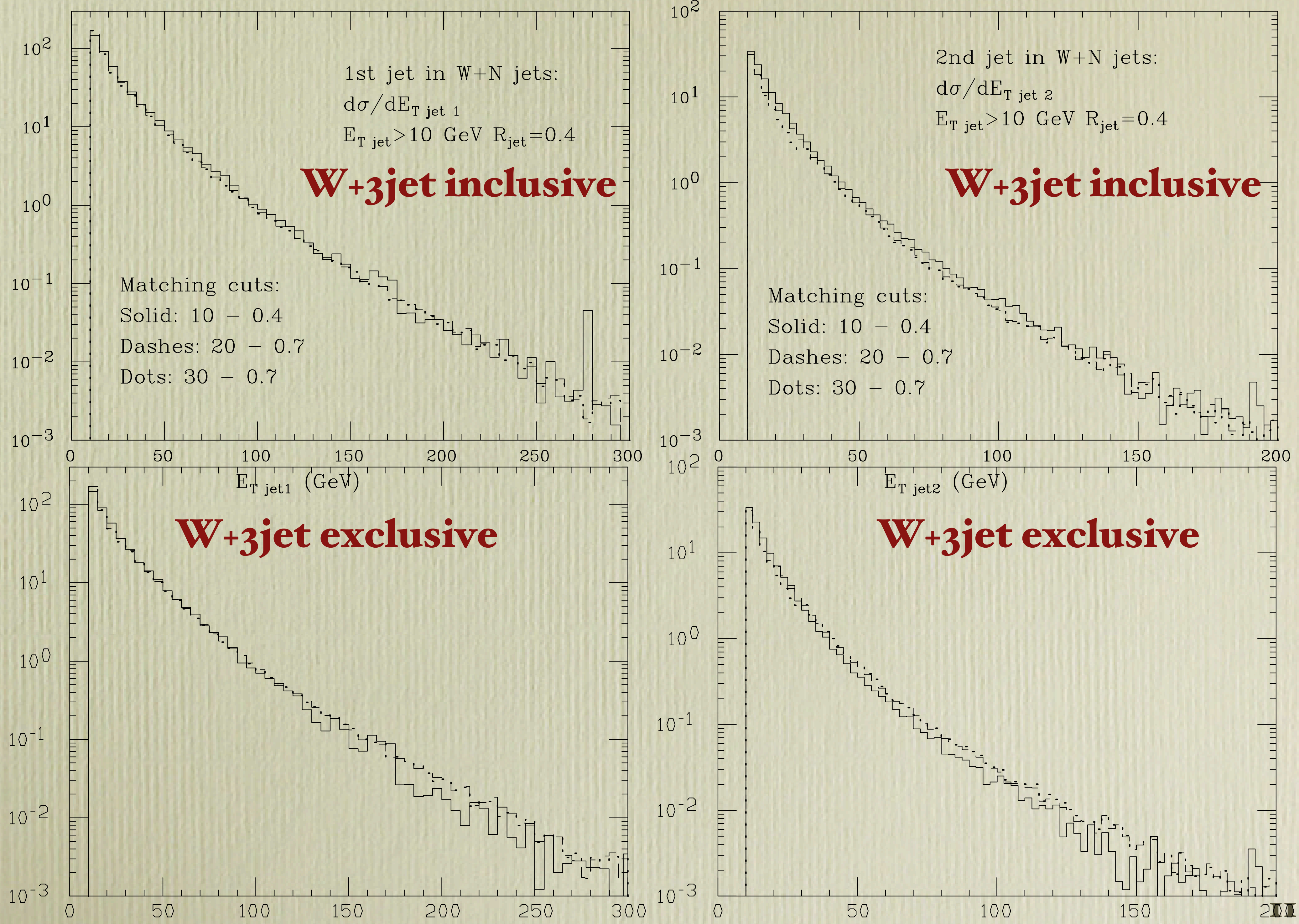


Leading jet



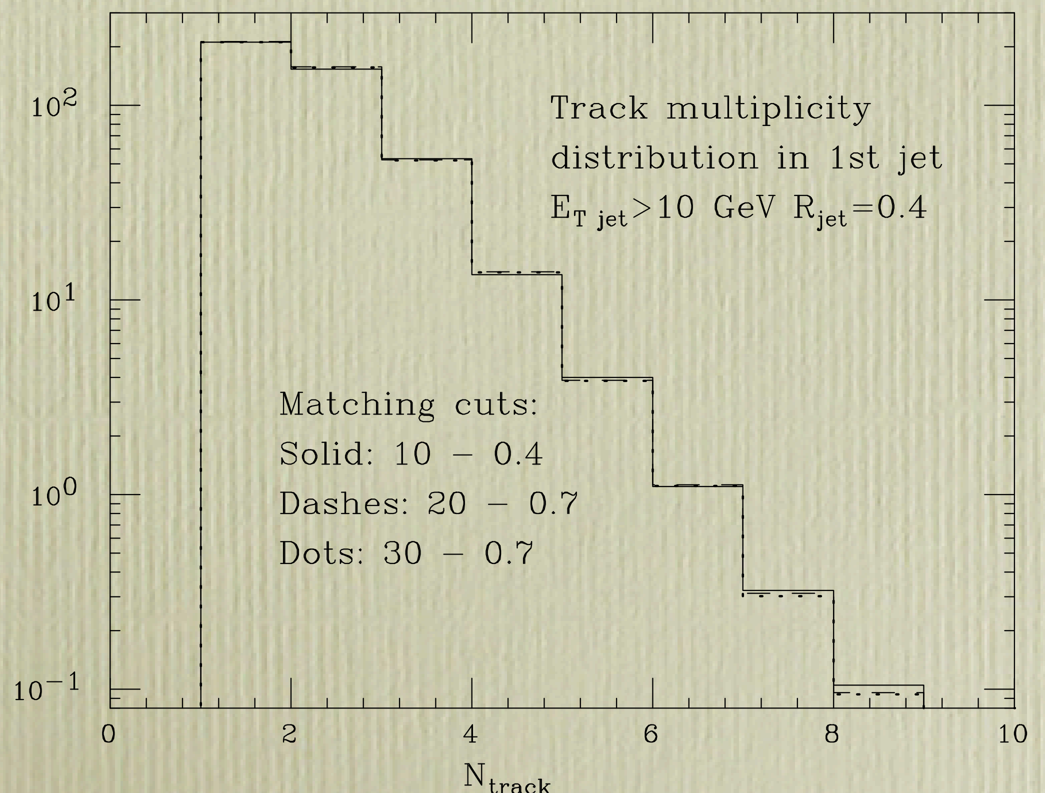
Second-E_T jet

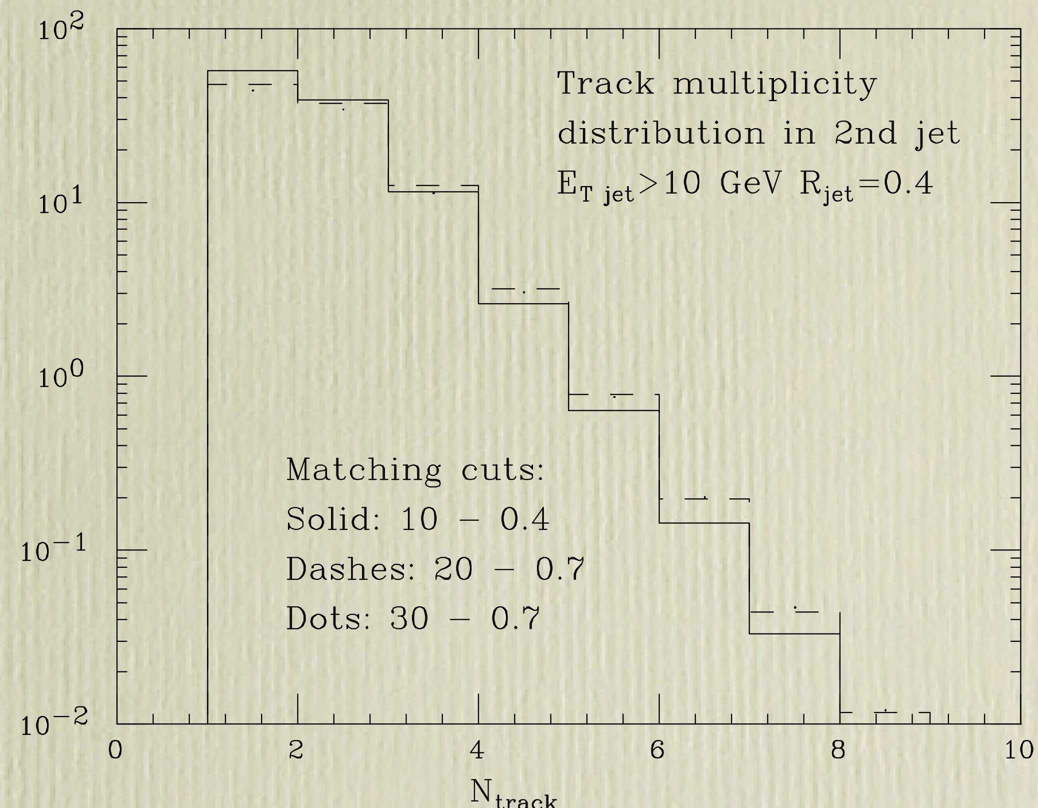
Impact of treating inclusively/exclusively the highest-multiplicity sample



Looking inside jets:
fragmentation properties of jets in samples defined by different matching thresholds

track ⇒ parton in the shower





Conclusions

- The matching procedure will be hard-wired into ALPGEN. Not only matching **doesn't need** to be done against jets defined after detector simulation: **it simply shouldn't.** "Matching" deals with a perturbation-theory issue (ambiguity in the separation between hard ME corrections and shower emissions), so any matching prescription should only deal with partons.
- The proposed matching prescription provides a **consistent way of defining fully inclusive multijet samples**, leading to results which are independent of the matching prescription, within the 20-30% uncertainties typical of a LL approach
- The stability w.r.t. to the generation cuts and matching criteria allows to **use parton-level thresholds tighter than the jet ones** (e.g. generate at [20 GeV, R=0.7] and properly describe [10 GeV, R=0.4] jets)

Addendum

Following the presentation by Mitch at the meeting, and being bothered by the results he obtained, I used the samples generated for the study described in this talk and tried to generate the distributions he presented. My definition of jets is not equivalent to his (I don't use HEPG jets), so the details do not need to coincide. Nevertheless, the shapes I obtain are very close to those obtained by Mitch using CKKW, while they have no resemblance wit those he obtained using "MLM matching".

In the following, I use the sample defined by:

Parton-level generation cuts:

$p_T > 10$ GeV $dR > 0.4$

MLM matching cuts:

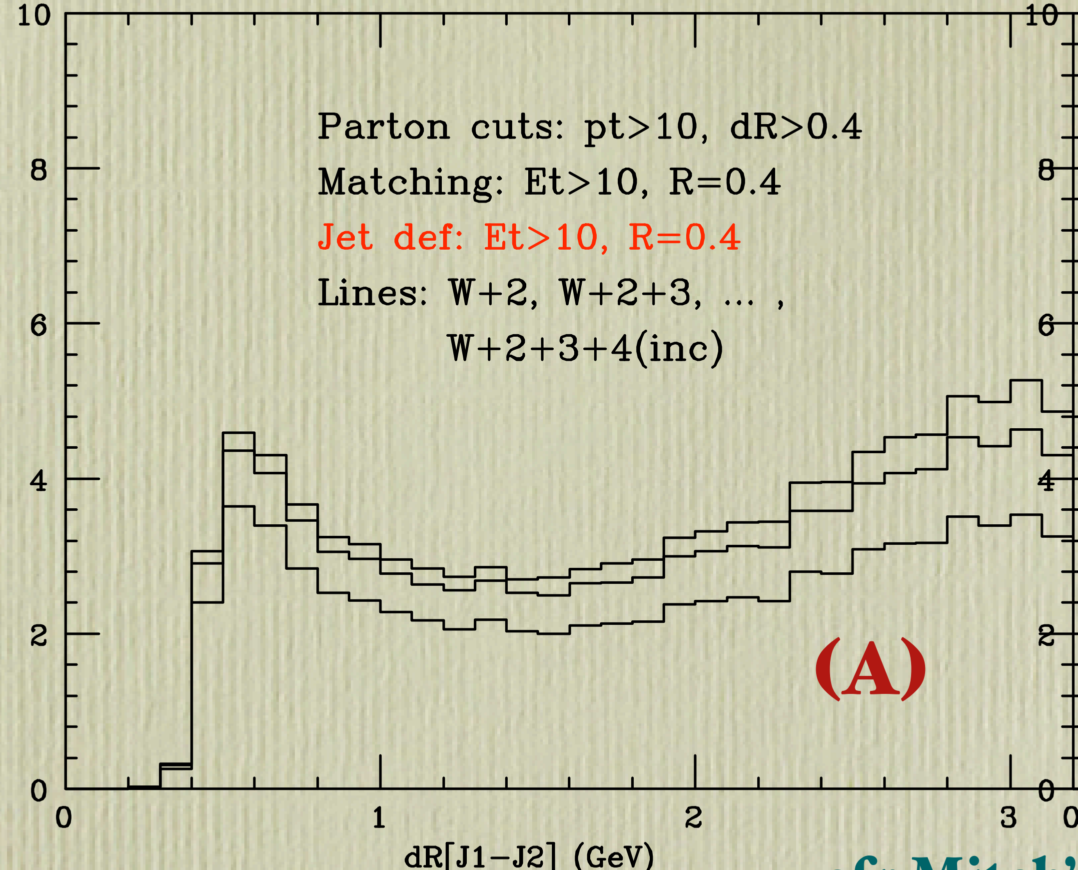
$E_{T\,jet} > 10$ GeV $R_{jet} = 0.4$

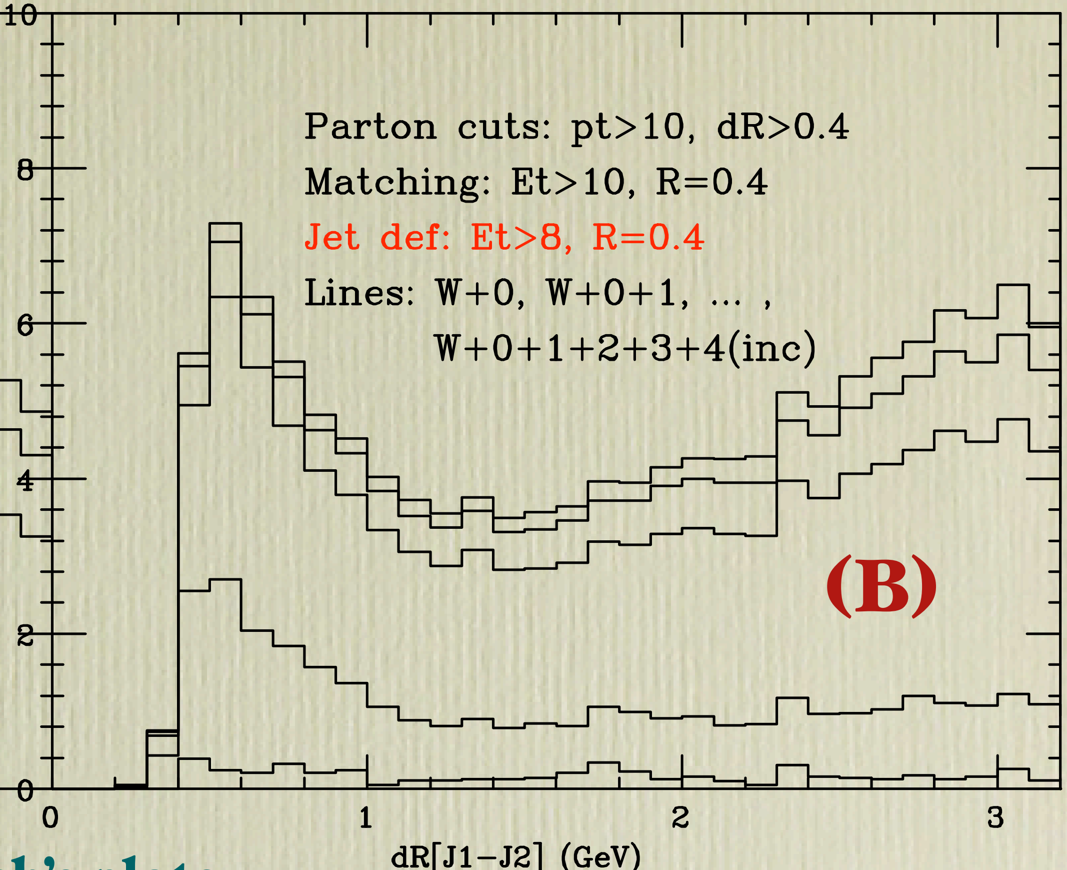
Jet definition for the plots:

(A): $E_{T\,jet} > 10$ GeV $R_{jet} = 0.4$

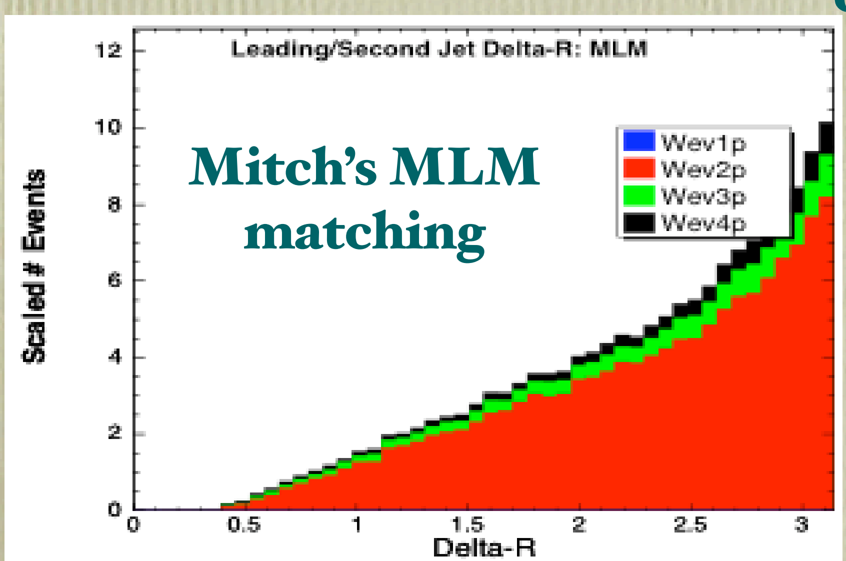
(B): $E_{T\,jet} > 8$ GeV $R_{jet} = 0.4$

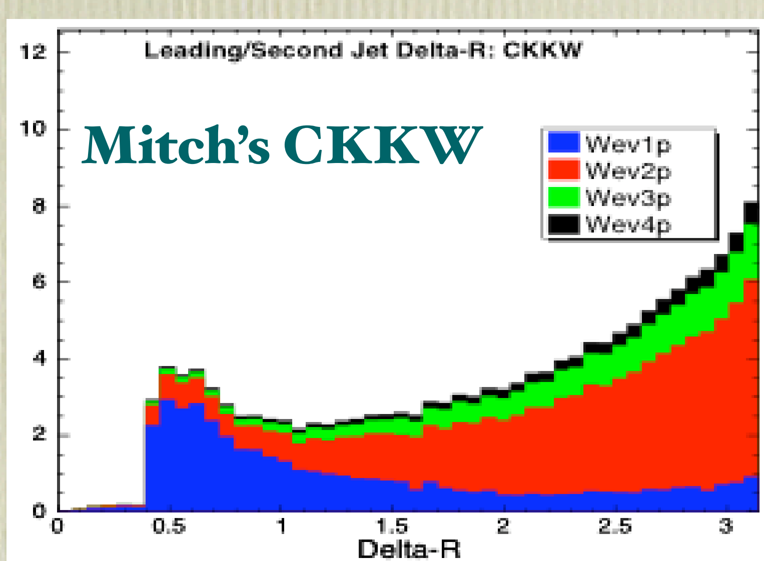
dR[1,2] spectra



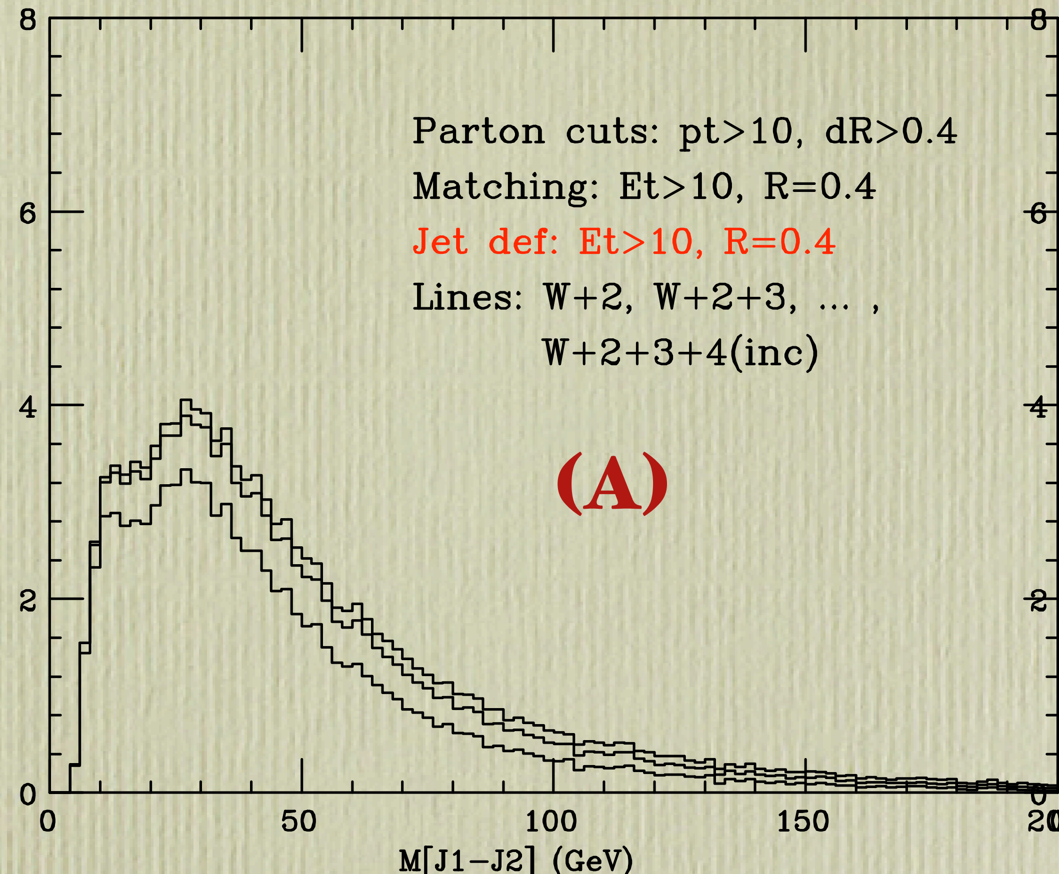


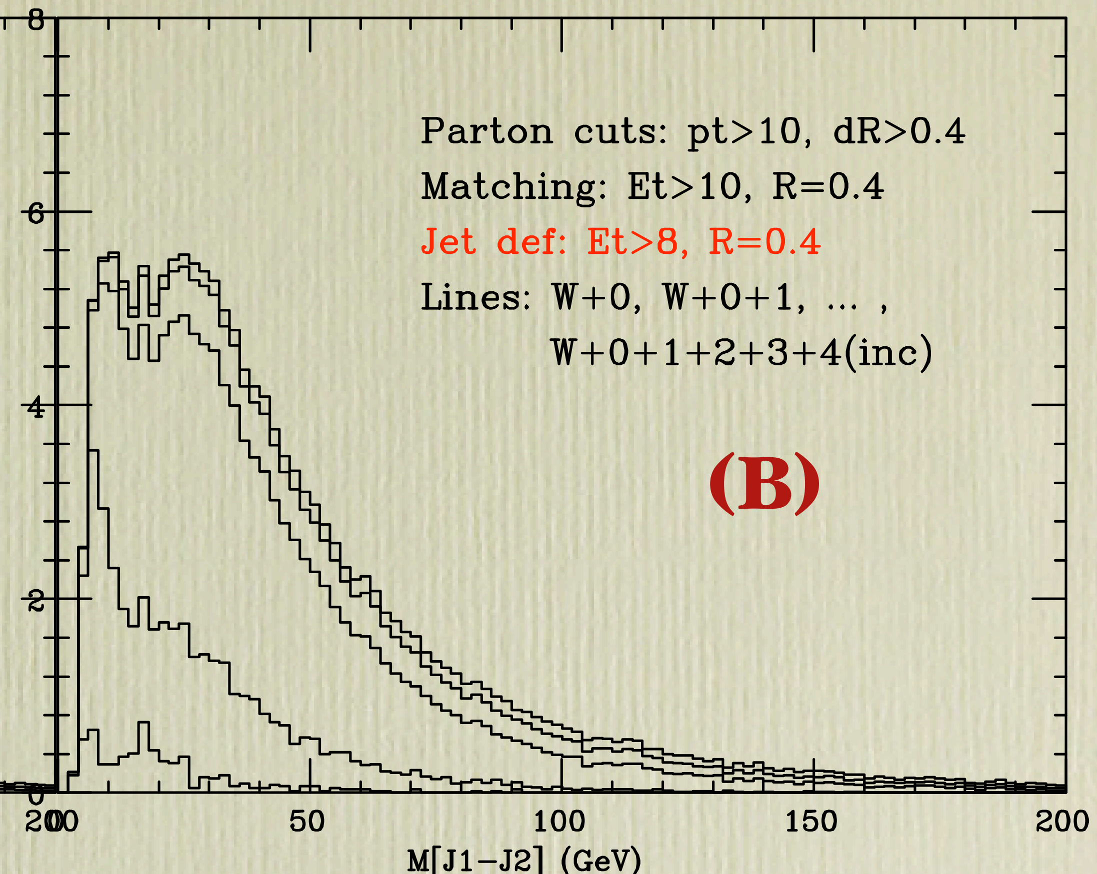
cfr Mitch's plots





M[1,2] spectra





cfr Mitch's plots