Matching/Merging Tutorial

matching in MadGraph+Pythia

Example: Simulation of pp→W with 0, 1, 2 jets (comfortable on a laptop)

```
mg5> generate p p > w+, w+ > l+ vl @0
mg5> add process p p > w+ j, w+ > l+ vl @1
mg5> add process p p > w+ j j, w+ > l+ vl @2
mg5> output
```

```
In run_card.dat:
…
  1 = ickkw
…
  0 = ptj
…
 15 = xqcut
```

- `1 = ickkw` — Matching on
- `0 = ptj` — No cone matching
- `15 = xqcut` — k_T matching scale

Matching automatically done when run through MadEvent and Pythia!

Merging scale can be defined in PY8 card (or left auto)

matching in MadGraph+Pythia

- By default, k_T-MLM matching is run if xqcut > 0, with the matching scale QCUT = max(xqcut*1.4, xqcut+10)
- For shower-kT, by default QCUT = xqcut
- If you want to change the Pythia setting for matching scale or switch to shower-k_T matching:

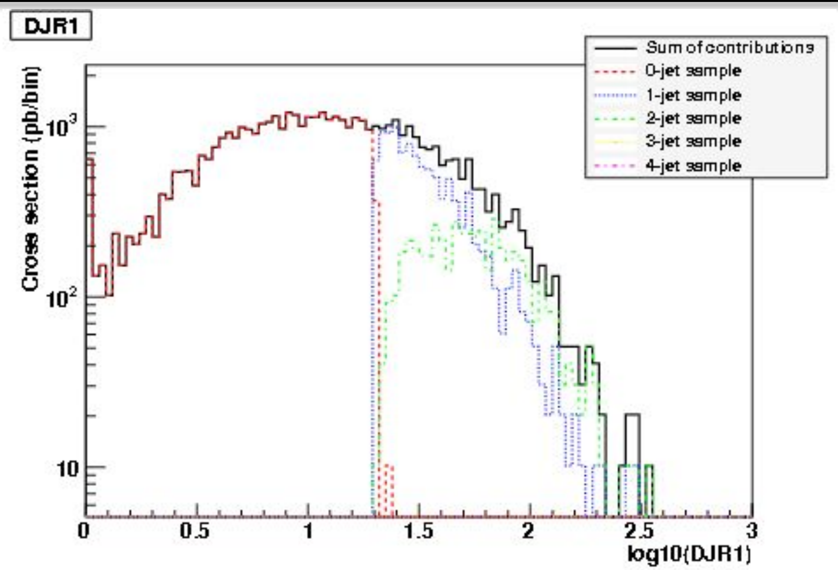
```
In pythia_card.dat:
…
! This sets the matching scale, needs to be > xqcut
QCUT = 30
! This switches from kT-MLM to shower-kT matching
! Note that MSTP(81)>=20 needed (pT-ordered shower)
SHOWERKT = T
```

How to do validate the matching

- The matching scale (QCUT) should typically be chosen around 1/6-1/2 x hard scale (so xqcut correspondingly lower)
- The matched cross section (for X+0,1,... jets) should be close to the unmatched cross section for the 0-jet sample (found on the process HTML page)
- The differential jet rate plots should be smooth
- When QCUT is varied (within the region of validity), the matched cross section or differential jet rates should not vary significantly

Differential Jet Rate Plot

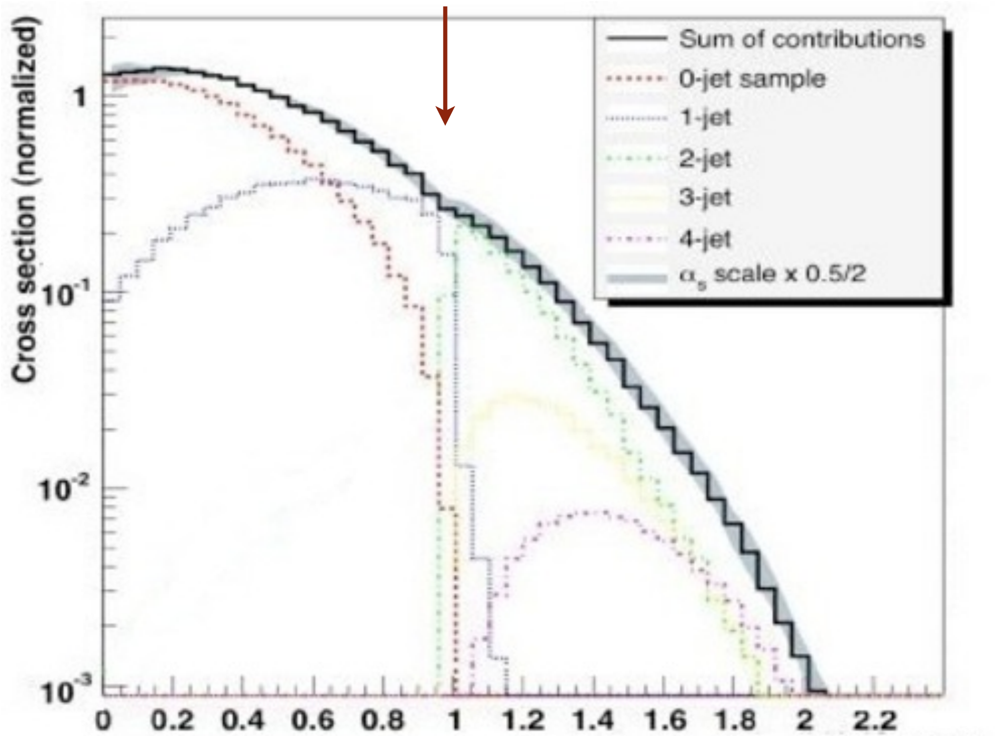
- This are the clustering scales in the kt-jet clustering scheme
- DJR1: pT of the last remaining jet
- DJR2: The minimum between the pT of the second to last remaining jet and the kt between the last two jet.
- Only radiative jet (not those from decay) should enter those plot.



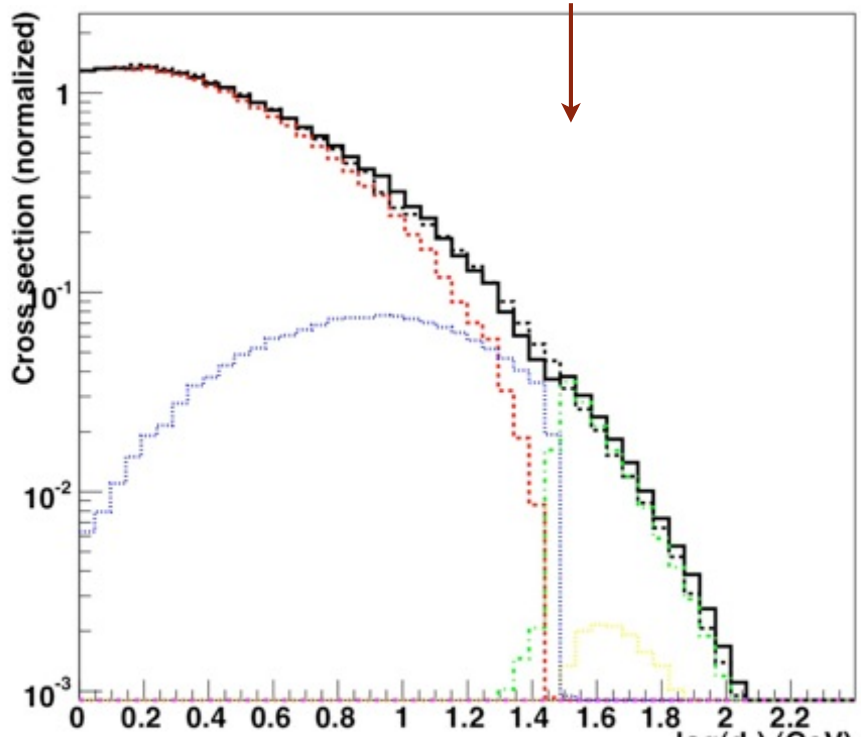
Matching Validation

W+jets production at the Tevatron for MadGraph+Pythia
(k_T-jet MLM scheme, q^2-ordered Pythia showers)

Q^{match} = 10 GeV



Q^{match} = 30 GeV



log(Differential jet rate for 1 → 2 radiated jets ~ pT(2nd jet))

Matching Validation

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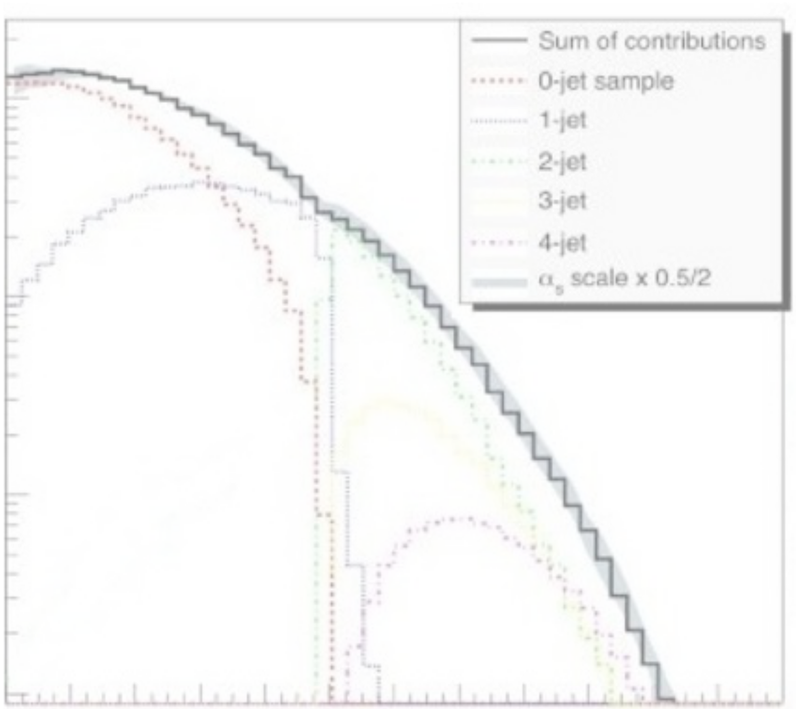
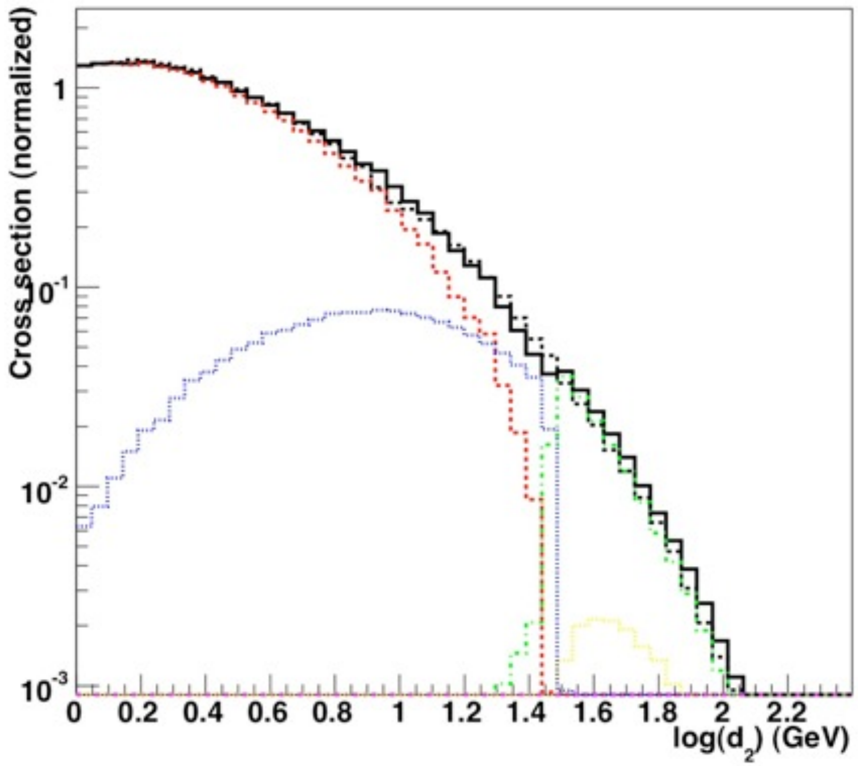




Jet distributions smooth, and stable when we vary the matching scale!

Lecture Summary

- Despite the apparent enormous complexity of simulation of complete collider events, nature has kindly allowed us to factorize the simulation into separate steps
- The Monte Carlo method allows us to step-by-step simulate hard scattering, parton shower, particle decays, hadronization, and underlying event
- Jet matching between matrix elements and parton showers gives crucial improvement of simulation of background as well as signal processes
- Running matching with MadGraph + Pythia is very easy, but the results should always be checked for consistency

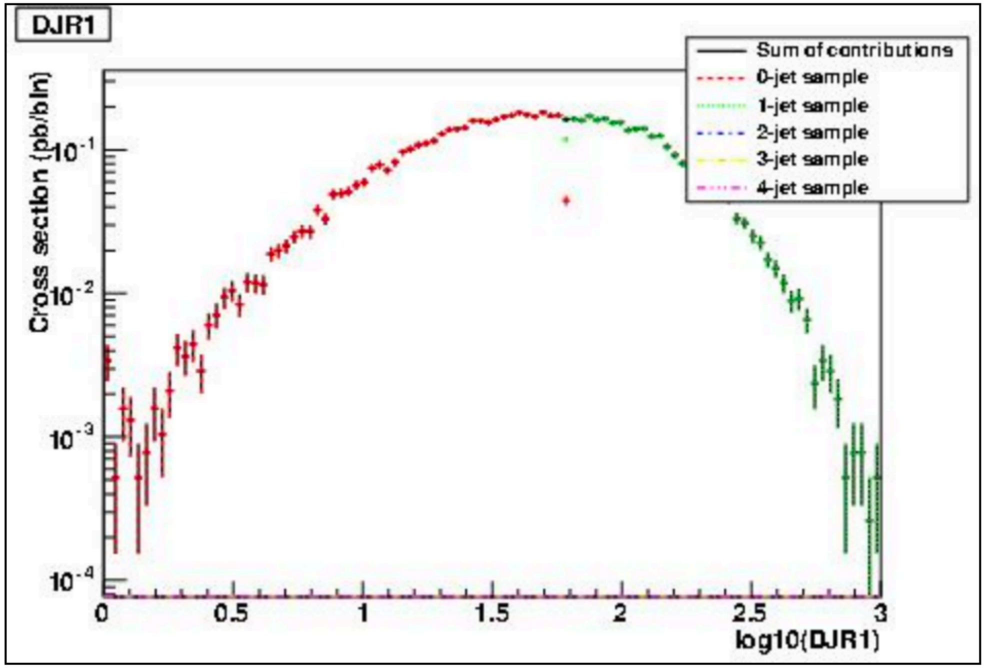
Tutorial:

- Generate p p > t t~
- Add process p p > t t~ j
- Output; Launch
  - ➡ Ask for MadSpin and Pythia8 and MA5
  - ➡ set mpi OFF # This is for speed issue for the tuto
  - ➡ decay t > w+ b, w+ > e+ ve
  - ➡ decay t~ > w- b~, w- > e- ve~
  - ➡ set xqcut 30 #minimal distance between quark/gluon @tree-level
  - ➡ set jetmatching:Qcut 60 #the MLM matching scale
- Check the plot

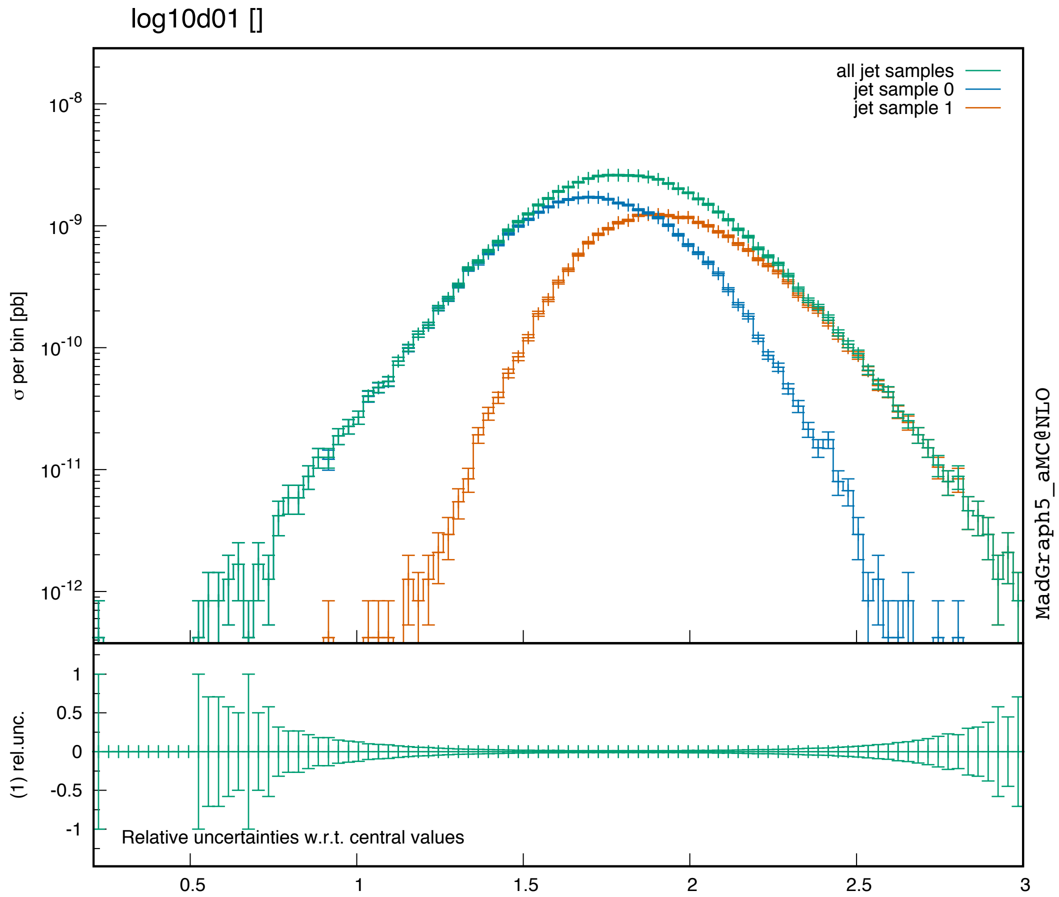
Tutorial II:

- Compute the cross-section (MLM merged)
- For p p > w+ and p p > w+ j
- Compute the cross-section for various value of the merging scale
  - Check the plot in the various cases

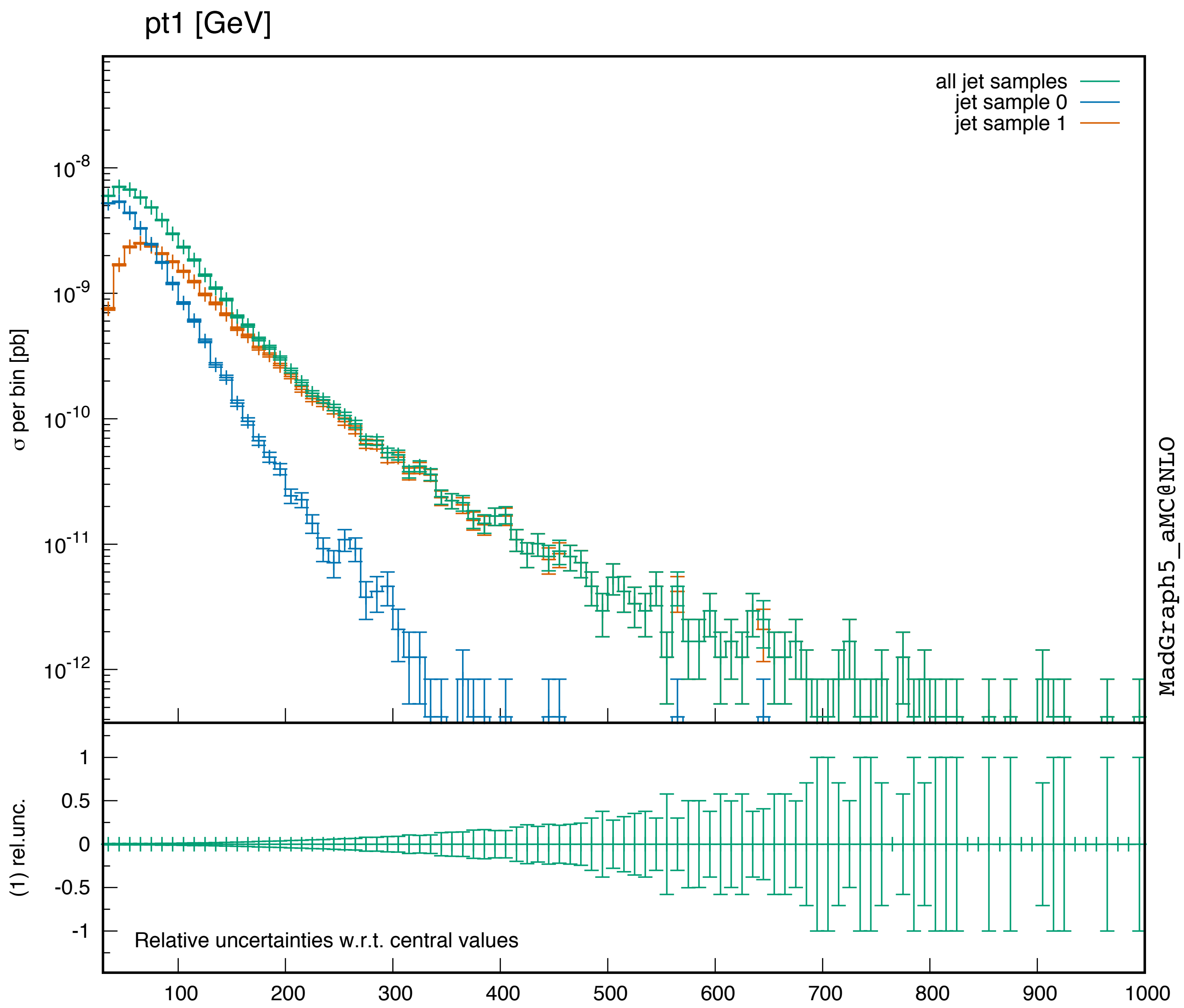
Validation of MLM



[Download PS DJR1.ps]



PT distribution



Exercise VI: Matching+Merging

	w+0j	w+1j	w+2j	w+3j
no matching	8,35E+04	1,58E+04	8,7E+03	3,5E+03

	1GeV	10GeV	20GeV	50GeV	100GeV	500GeV
w+0	8,35E+04	8,35E+04	8,35E+04	8,35E+04	8,35E+04	8,35E+04
0+1	1,07E+05	9,09E+04	8,91E+04	8,61E+04	8,40E+04	8.35+04
0+1+2	1,12E+05	9,29E+04	9,03E+04	8,66E+04	8,44E+04	8,35E+04
0+1+2+3	1,20E+05	9,47E+04	9,07E+04	8,68E+04	8,40E+04	8,35E+04

Slow → Fast

low efficiency → High efficiency

Exercise VI: Matching+Merging

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w+0	8,35E+04	8,35E+04	8,35E+04	8,35E+04	8,35E+04	8,35E+04
0+1	1,07E+05	9,09E+04	8,91E+04	8,61E+04	8,40E+04	8.35+04
0+1+2	1,12E+05	9,29E+04	9,03E+04	8,66E+04	8,44E+04	8,35E+04
0+1+2+3	1,20E+05	9,47E+04	9,07E+04	8,68E+04	8,40E+04	8,35E+04

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w+0	8,35E+04	8,35E+04	8,35E+04	8,35E+04	8,35E+04	8,35E+04
0+1	1,07E+05	9,09E+04	8,91E+04	8,61E+04	8,40E+04	8.35+04
0+1+2	1,12E+05	9,29E+04	9,03E+04	8,66E+04	8,44E+04	8,35E+04
0+1+2+3	1,20E+05	9,47E+04	9,07E+04	8,68E+04	8,40E+04	8,35E+04

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w+0	8,35E+04	8,35E+04	8,35E+04	8,35E+04	8,35E+04	8,35E+04
0+1	1,07E+05	9,09E+04	8,91E+04	8,61E+04	8,40E+04	8.35+04
0+1+2	1,12E+05	9,29E+04	9,03E+04	8,66E+04	8,44E+04	8,35E+04
0+1+2+3	1,20E+05	9,47E+04	9,07E+04	8,68E+04	8,40E+04	8,35E+04

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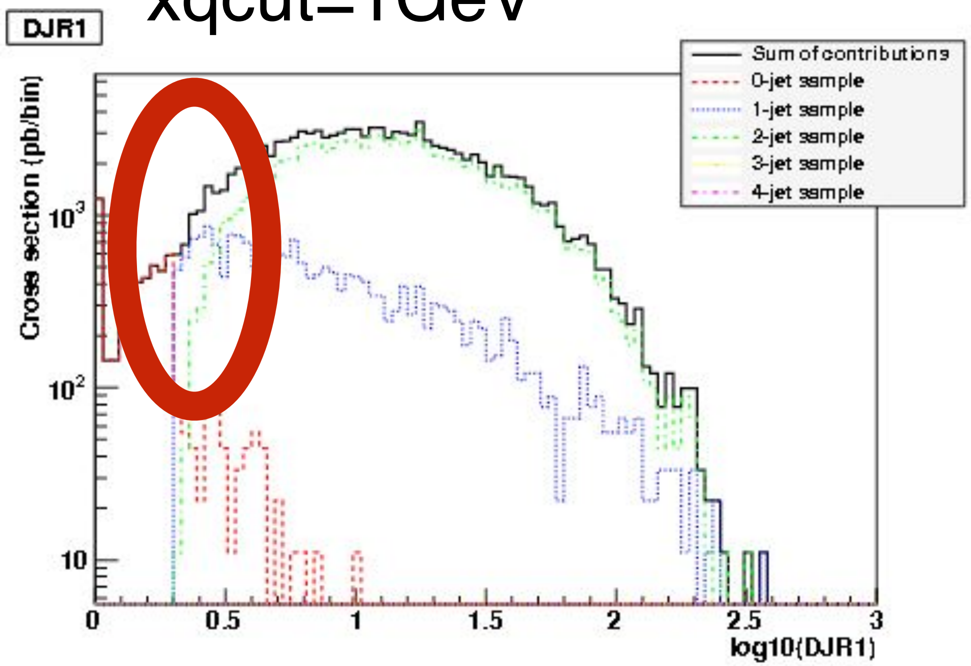
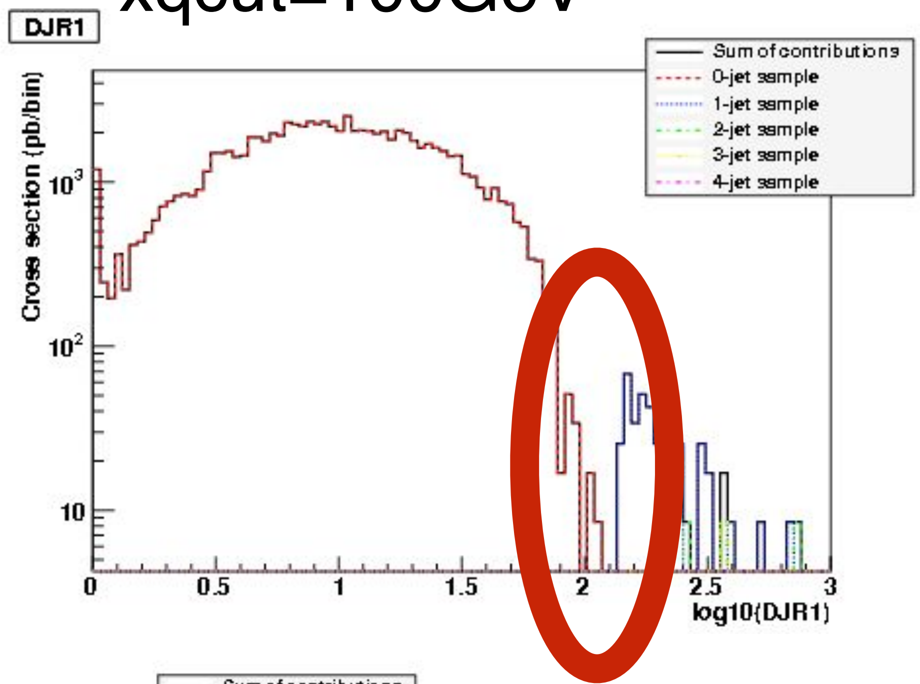
	w+0j	w+1j	w+2j	w+3j
no matching	8,35E+04	1,58E+04	8,7E+03	3,5E+03

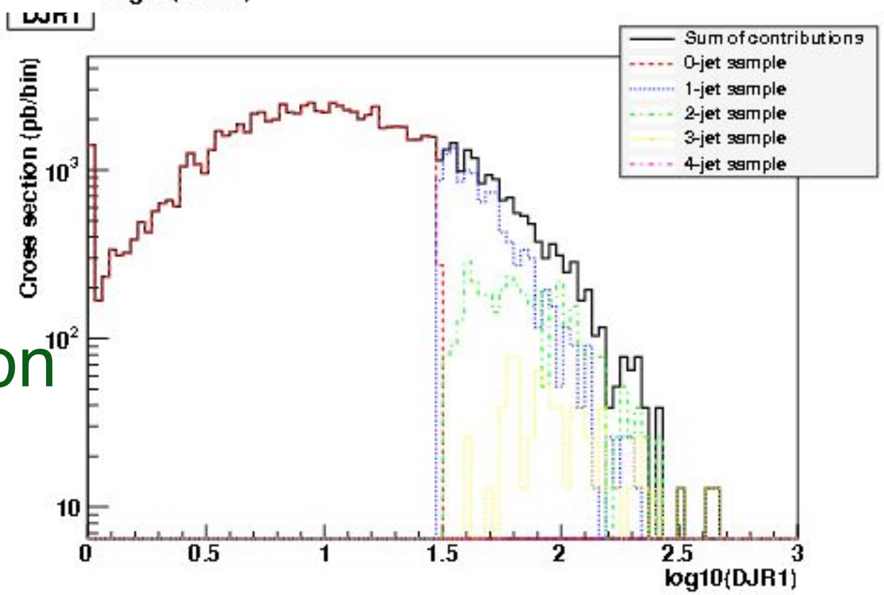
	1GeV	10GeV	20GeV	50GeV	100GeV	500GeV
w+0	8,35E+04	8,35E+04	8,35E+04	8,35E+04	8,35E+04	8,35E+04
0+1	1,07E+05	9,09E+04	8,91E+04	8,61E+04	8,40E+04	8.35+04
0+1+2	1,12E+05	9,29E+04	9,03E+04	8,66E+04	8,44E+04	8,35E+04
0+1+2+3	1,20E+05	9,47E+04	9,07E+04	8,68E+04	8,40E+04	8,35E+04

xqcut=1GeV



xqcut=100GeV





xqcut=20GeV

smooth transition

Exercise VI: Matching+Merging

	w+0j	w+1j	w+2j	w+3j
no matching	8,35E+04	1,58E+04	8,7E+03	3,5E+03

	1GeV	10GeV	20GeV	50GeV	100GeV	500GeV
w+0	8,35E+04	8,35E+04	8,35E+04	8,35E+04	8,35E+04	8,35E+04
0+1	1,07E+05	9,[illegible]9E+04	8,91E+04	8,61E+04	8,40E+04	8.35+04
0+1+2	1,12E+05	9,29E+04	9,03E+04	8,66E+04	8,44E+04	8,35E+04
0+1+2+3	1,20E+05	9,47E+04	9,07E+04	8,68E+04	8,40E+04	8,35E+04