NLO / Loop Induced

- check that everything is working @NLO
  - ➡ p p > mu+ mu- [QCD]
  - ➡ p p > t t~ [QCD]
- Compare for your BSM model
  - ➡ p p > uv uv~ @LO and @NLO
  - ➡ perform the decay of uv uv~ with full spin correlation

- generate g g > h j in heft (Effective Field Theory)
- Do the same in the SM with the full loop
- Compare

Exercise 1: Matching

1. Generate p p > w+ with 0 jets, 0,1 jets and 0,1,2 jets
   (Each on different computers - use the most powerful computer for 0,1,2 jets)
   a. Generate 20,000 events for a couple of different xqcut values.
   b. Compare the distributions (before and after Pythia) and cross sections (before and after Pythia) between the different processes, and between the different xqcut values.
   c. Summarize: How many jets do we need to simulate? What is a good xqcut value? How are the distributions affected?

Matching (reminder)

Merging ME with PS

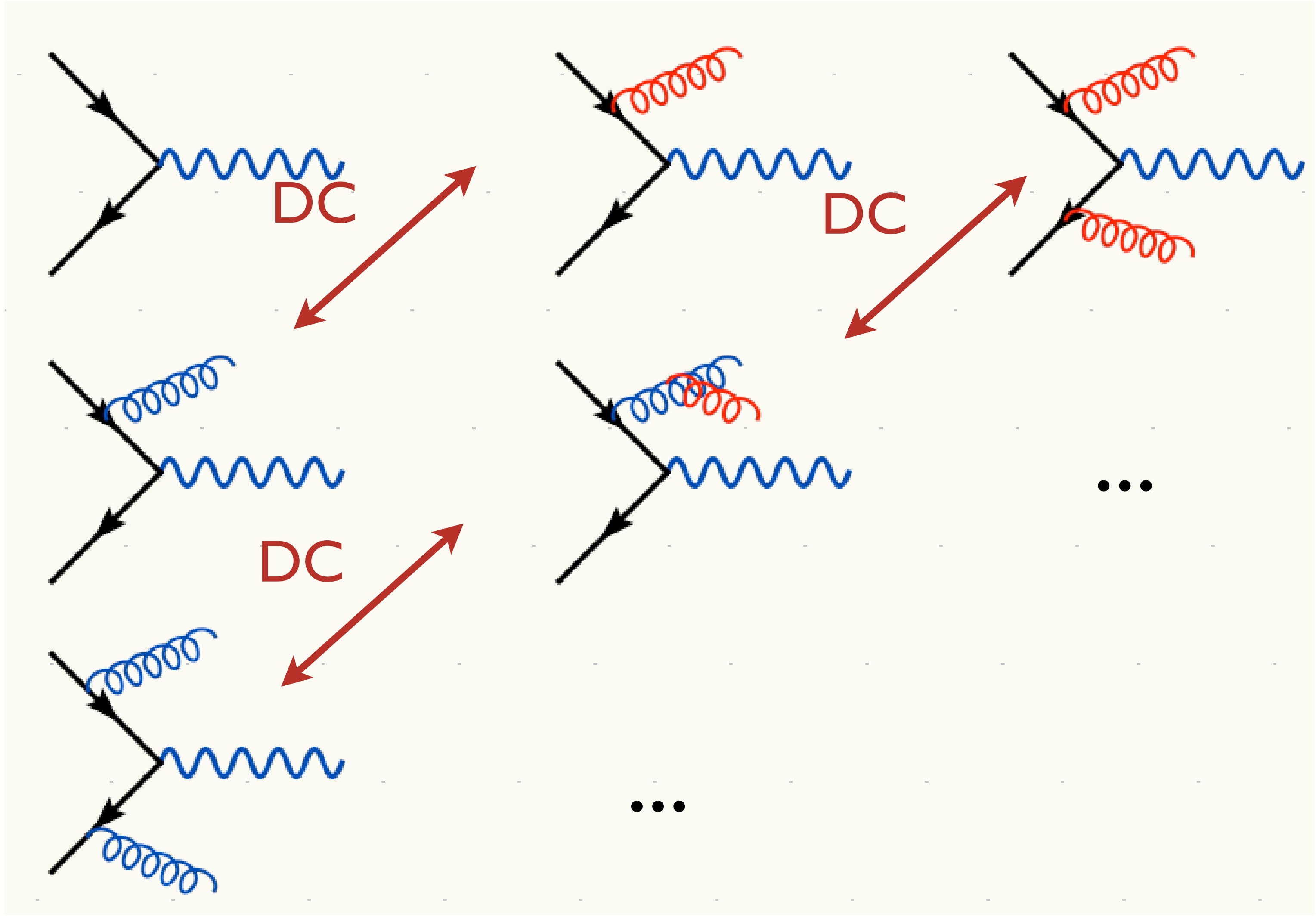
[Mangano]
[Catani, Krauss, Kuhn, Webber]

PS →

$pp \to W^+$

$pp \to W^+ j$ ME ↓

$pp \to W^+ jj$

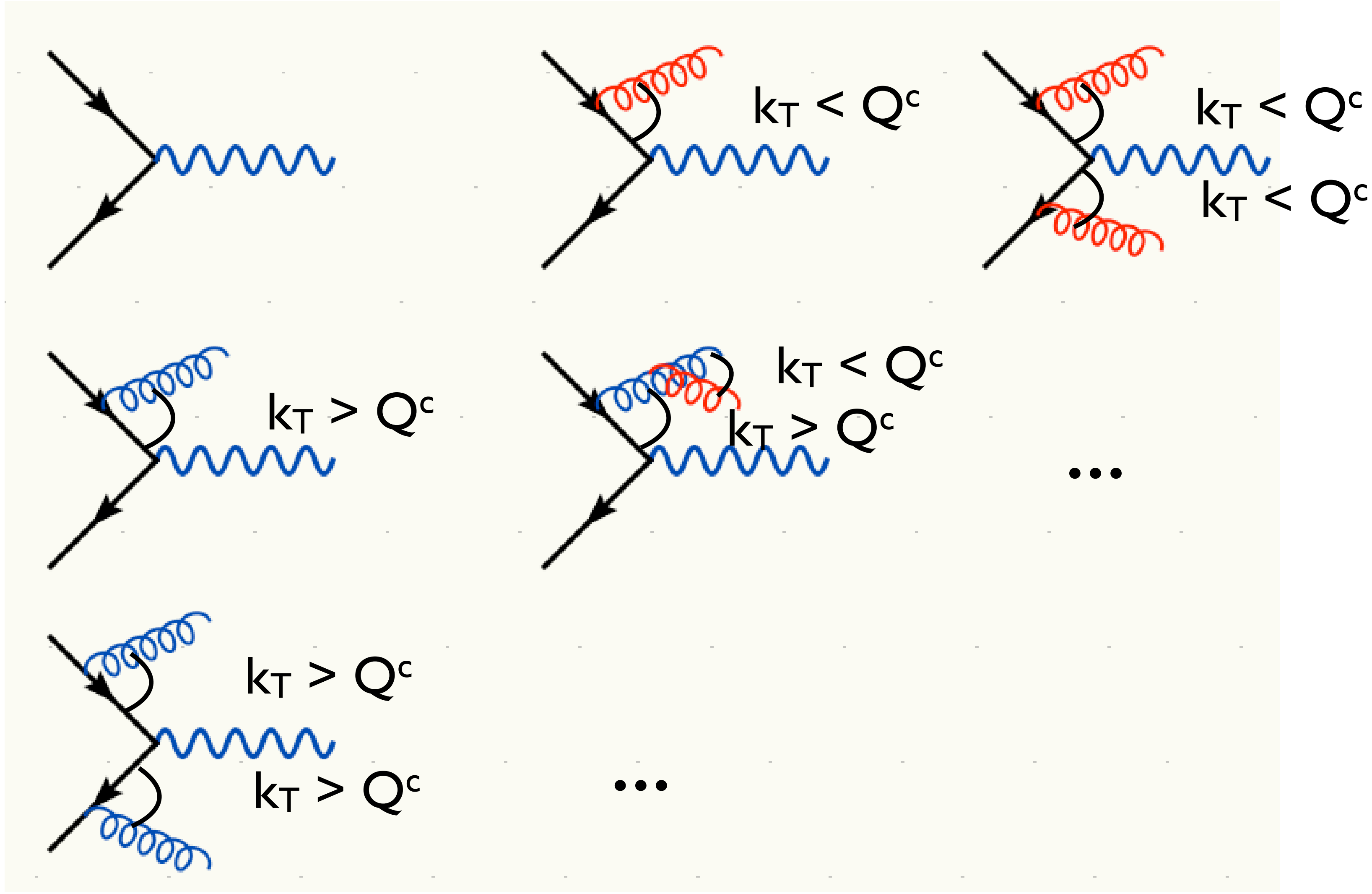


Merging ME with PS

[Mangano]
[Catani, Krauss, Kuhn, Webber]

PS →

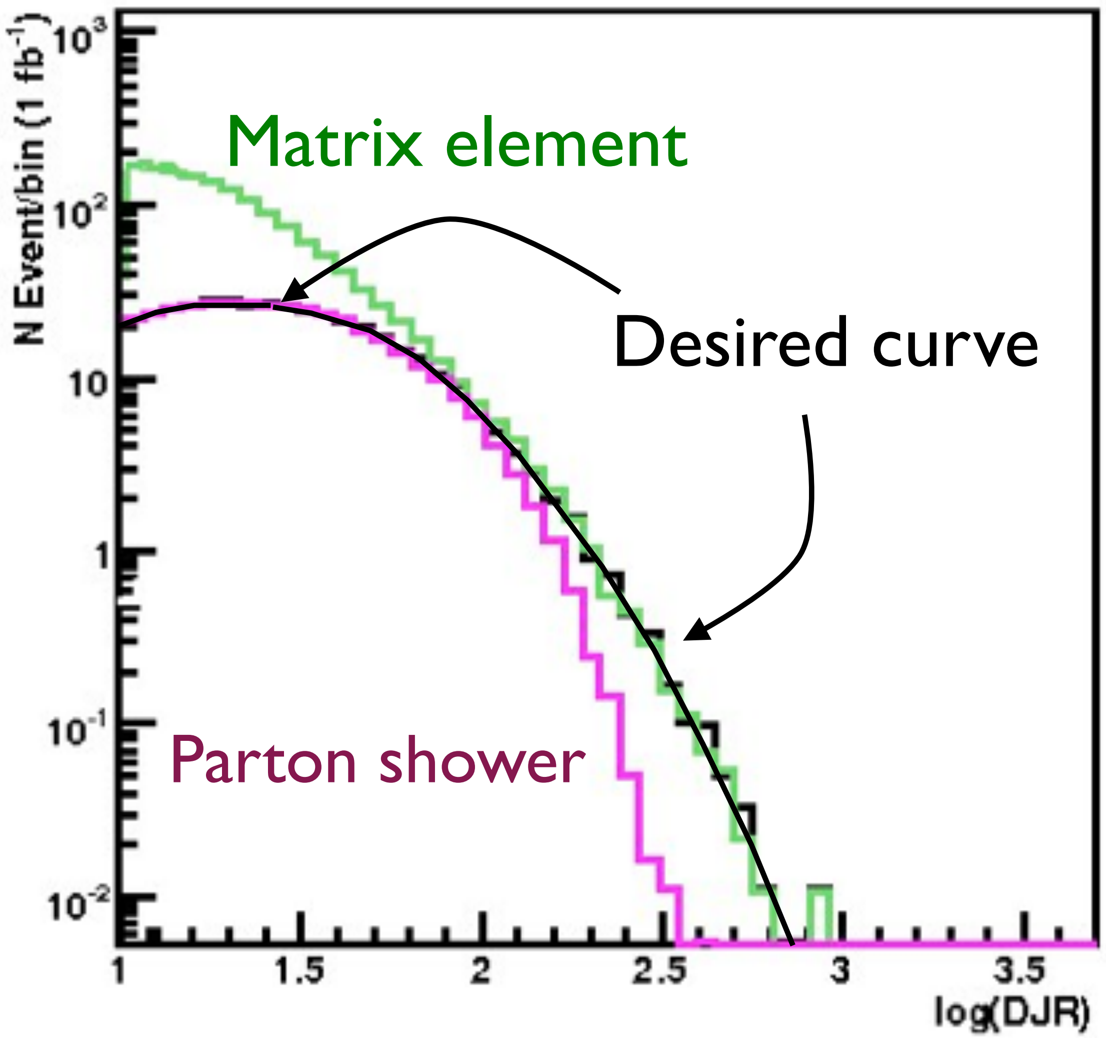
ME ↓



Double counting between ME and PS easily avoided using phase space cut between the two: PS below cutoff, ME above cutoff.

Goal for ME-PS merging/matching

- Regularization of matrix element divergence
- Correction of the parton shower for large momenta
- Smooth jet distributions



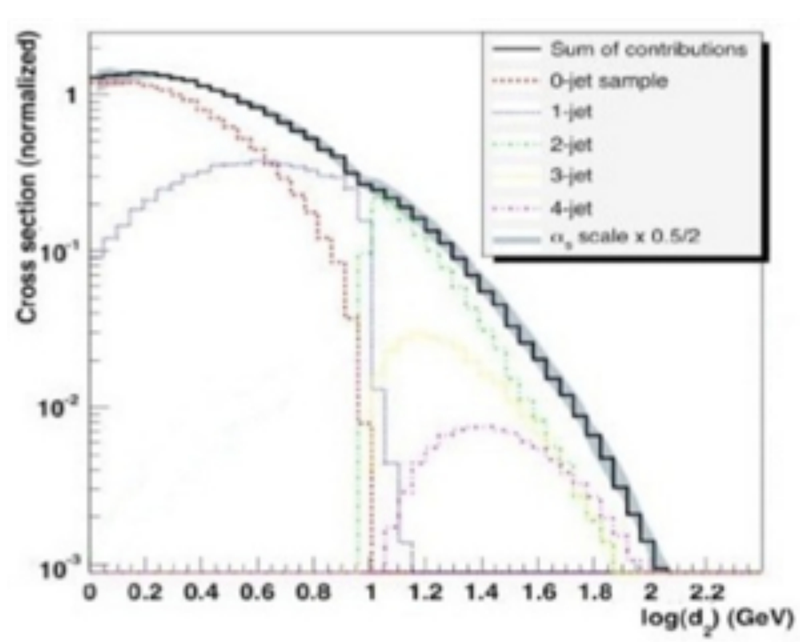
2nd QCD radiation jet in top pair production at the LHC, using MadGraph + Pythia

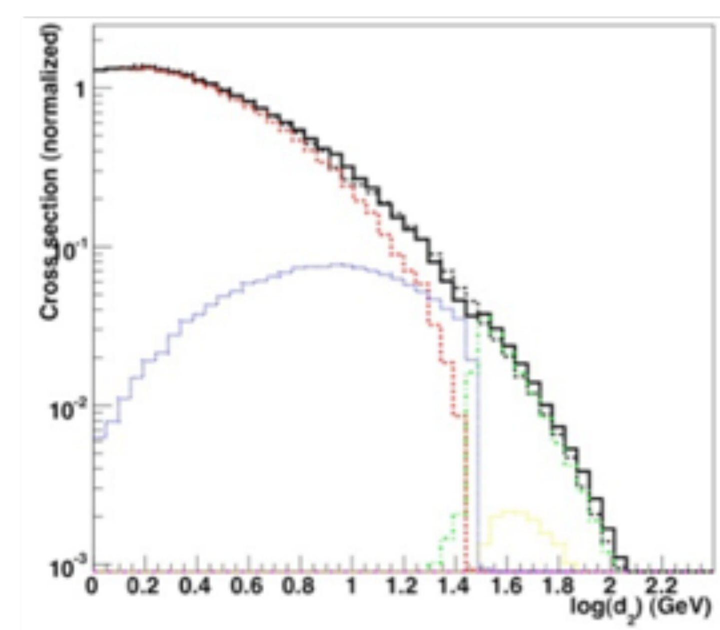
Summary of Matching Procedure

1. Generate ME events (with different parton multiplicities) using parton-level cuts ($p_T^{ME}/\Delta R$ or k_T^{ME})
2. Cluster each event and reweight α_s and PDFs based on the scales in the clustering vertices
3. Apply Sudakov factors to account for the required non-radiation above clustering cutoff scale and generate parton shower emissions below clustering cutoff:
   a. (CKKW) Analytical Sudakovs + truncated showers
   b. (CKKW-L) Sudakovs from truncated showers
   c. (MLM) Sudakovs from reclustered shower emissions

Validation

- 1. The matching scale (QCUT) should typically be chosen around 1/6-1/2 x hard scale (so xqcut correspondingly lower)
- 2.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)
- 3. The DJR should be smooth





How to.

- generate the diagram with
  - ➡ generate
  - ➡ add process
- output
- launch
  - ➡ ask to run pythia
  - ➡ In run_card: put icckw=1
    - ✦ set the value for xqcut
  - ➡ In pythia_card set a value for qcut

- Qcut is the matching scale (the separation between the shower and the matrix element
- xqcut should be strictly lower (by at least 10-15GeV) than qcut

Solution

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

	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

- No effect of the matching for 0 jet sample.

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

- matching scale too high only the 0 jet sample contributes => all radiations are from pythia

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

- matching scale too low. Only highest multiplicity sample contributes and low efficiency

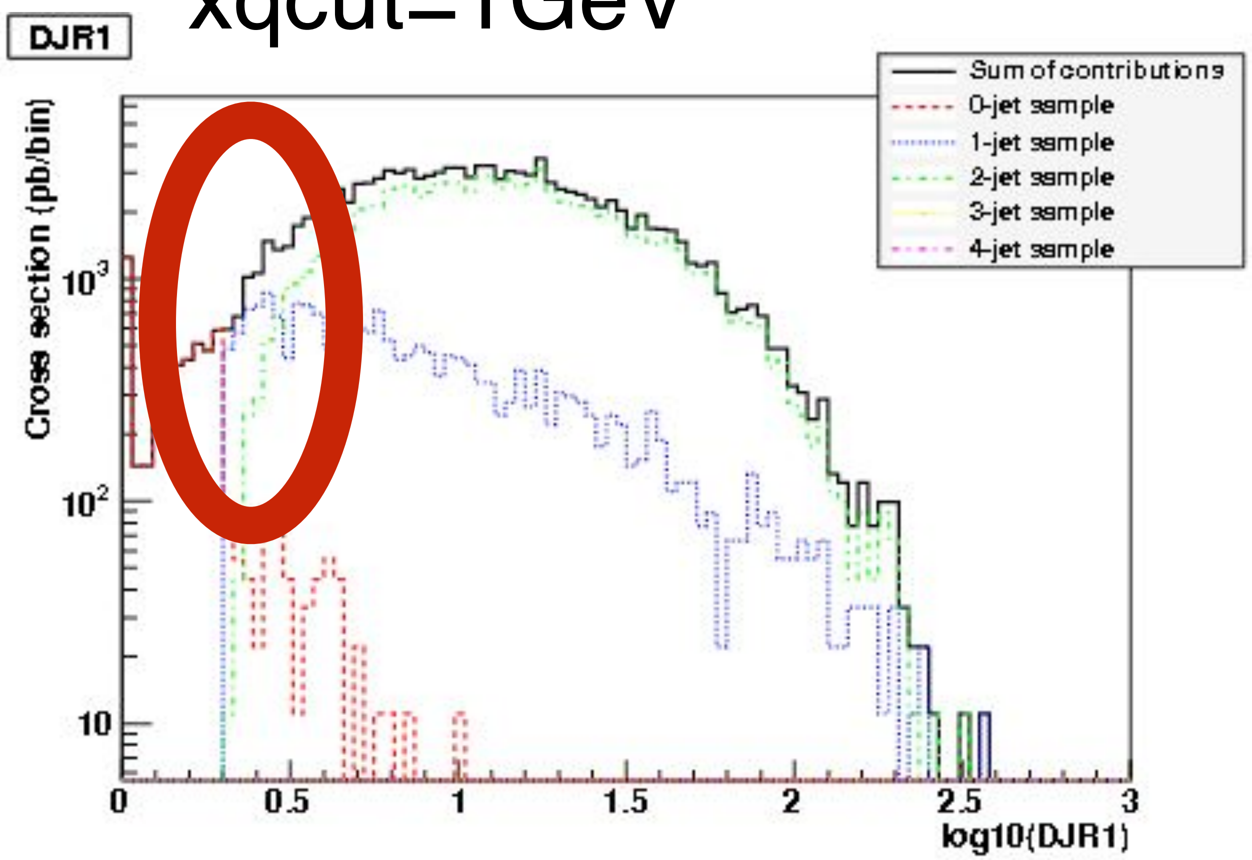
Exercise VI: Matching+Merging

	w+0j	w+1j	w+2j	w+3j
no matching	8.35E+04	1.58E+04	8.7E+03	3.5E+03

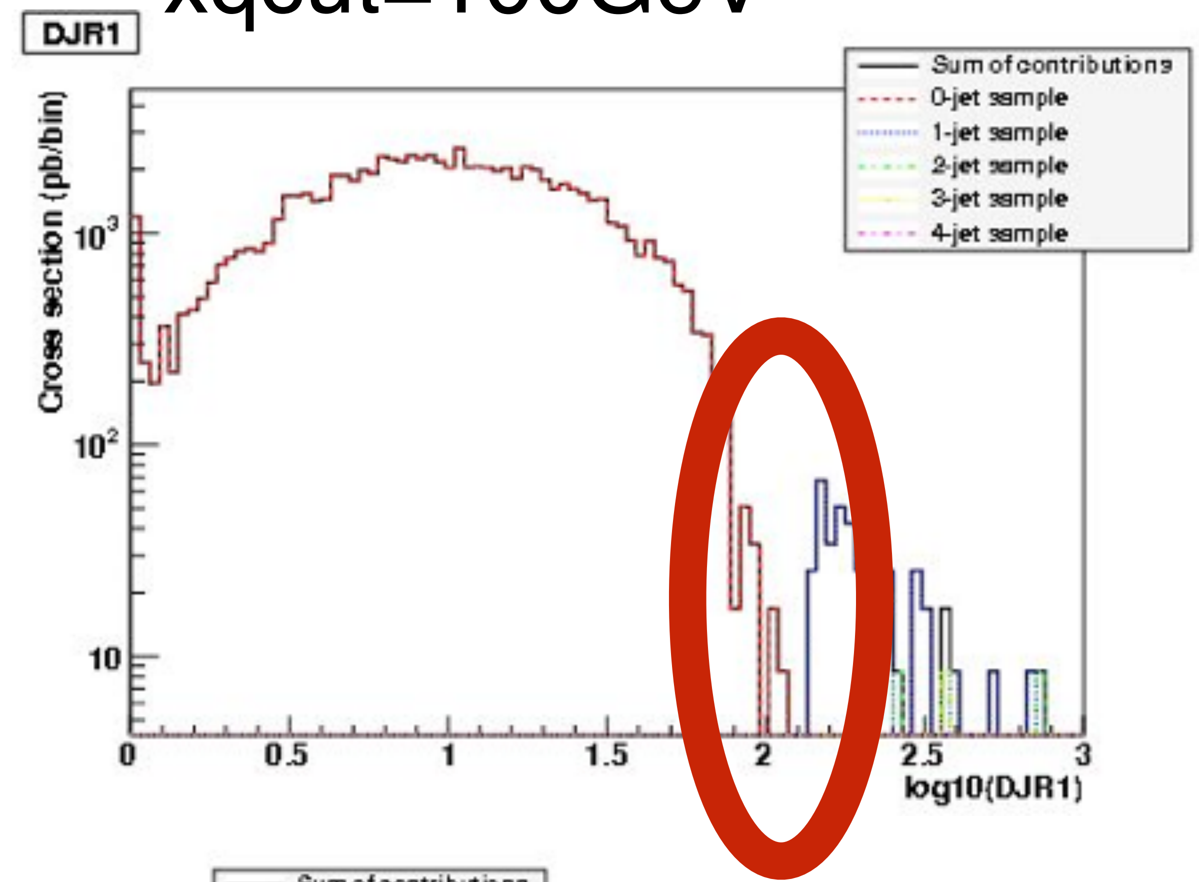
	1GeV	10GeV	20GeV	50GeV	100GeV	500GeV
w+0	8.35E+04	8.35E+04	8.35E+04	8.35E+04	8.35E+04	8.35E+04
0+1	1.07E+05	9.09E+04	8.91E+04	8.61E+04	8.40E+04	8.35+04
0+1+2	1.12E+05	9.29E+04	9.03E+04	8.66E+04	8.44E+04	8.35E+04
0+1+2+3	1.20E+05	9.47E+04	9.07E+04	8.68E+04	8.40E+04	8.35E+04

- Wrong differential rate plot. so to discard.

xqcut=1GeV

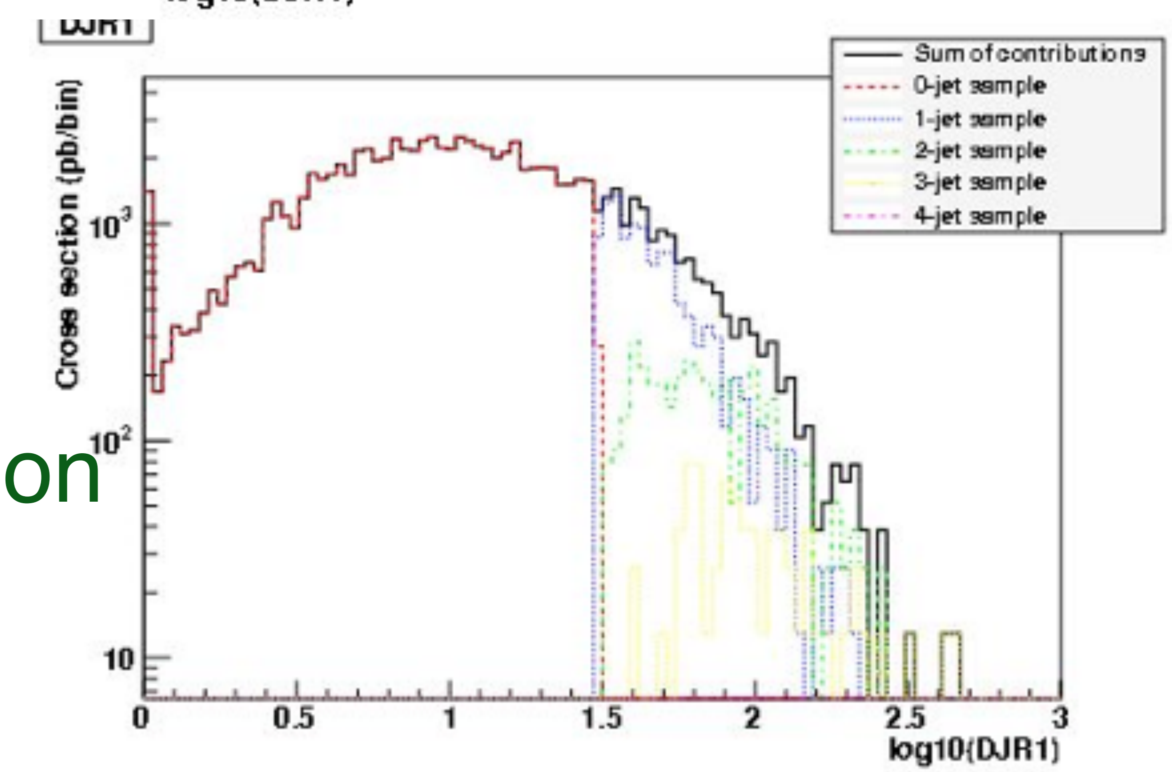


xqcut=100GeV



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

- Relatively stable cross-section! Important check.
- Close to the unmatched 0j cross-section