Production of gauge bosons in high-energy final states ($\sqrt{s} \gg M_V$)

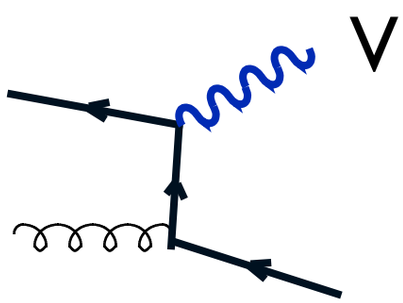
M.L. Mangano, QCD< EW, tools at 100 TeV Workshop, CERN, October 7-9 2015

Goals:

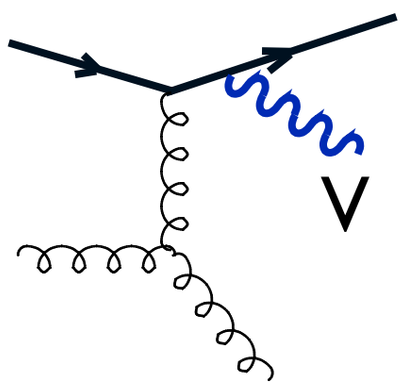
- the goal is not to provide the most accurate prediction of VB production, but to inspect individual contributions, extract an interpretation for the concept of "emission probabilities", which is often used in these high-E regimes
- analyze in detail the kinematics of vector boson radiation in high-ET events
- provide reference distributions to be used for comparison against the parton-shower approach to VB emission
- evaluate reliability of "Sudakov-log" approximation to gauge boson emission rates at high energy

Gauge boson emission from quarks

O(α_s)



⇒ $\sqrt{s} \approx p_T^V \gg M_V$



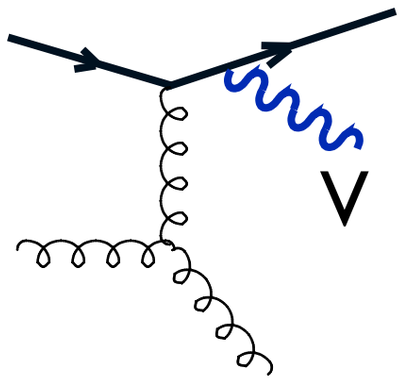
O(α_s^2), but enhanced by t-channel g exchange, and by $\log(p_T^{jet}/M_W)$

⇒ could be larger than O(α_s)
⇒ no strong ordering between p_T^V and M_V

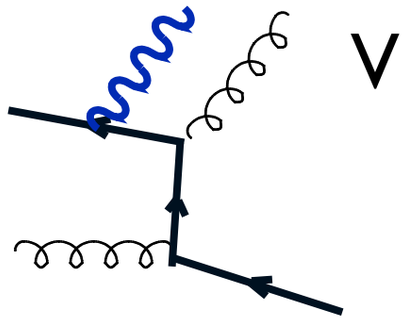
- Need to include $O(\alpha_S^2)$ in order to capture all sources of V production.
- This requires, in principle, the complete $O(\alpha_S^2)$ calculation, inclusive of virtual corrections to $O(\alpha_S)$.
- But the contribution from the soft-jet region to the enhanced EW logs is marginal, so one can define observables which are insensitive to the jet Sudakov region

In practice, I will consider p_T>30 GeV for both jets, and explore the TeV region for E_T(leading jet)

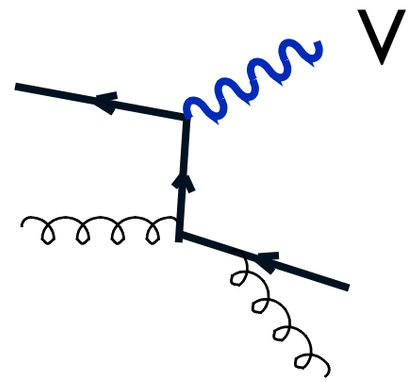
Study V emission rate in dijet events at very large $E_T^{(\text{leading jet})}$



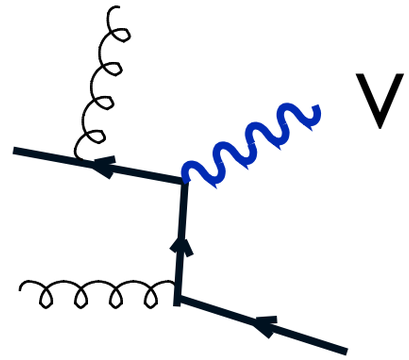
Large EW logs,
V correlated to jet



Large EW logs,
V not correlated to jet



Radiative correction to V +jet, no EW log



Radiative correction to V +jet, no EW log

Study σ(jet jet + V) / σ(jet jet) vs $E_T^{(\text{leading jet})}$

Define

$d\sigma_{jj}(W)$:

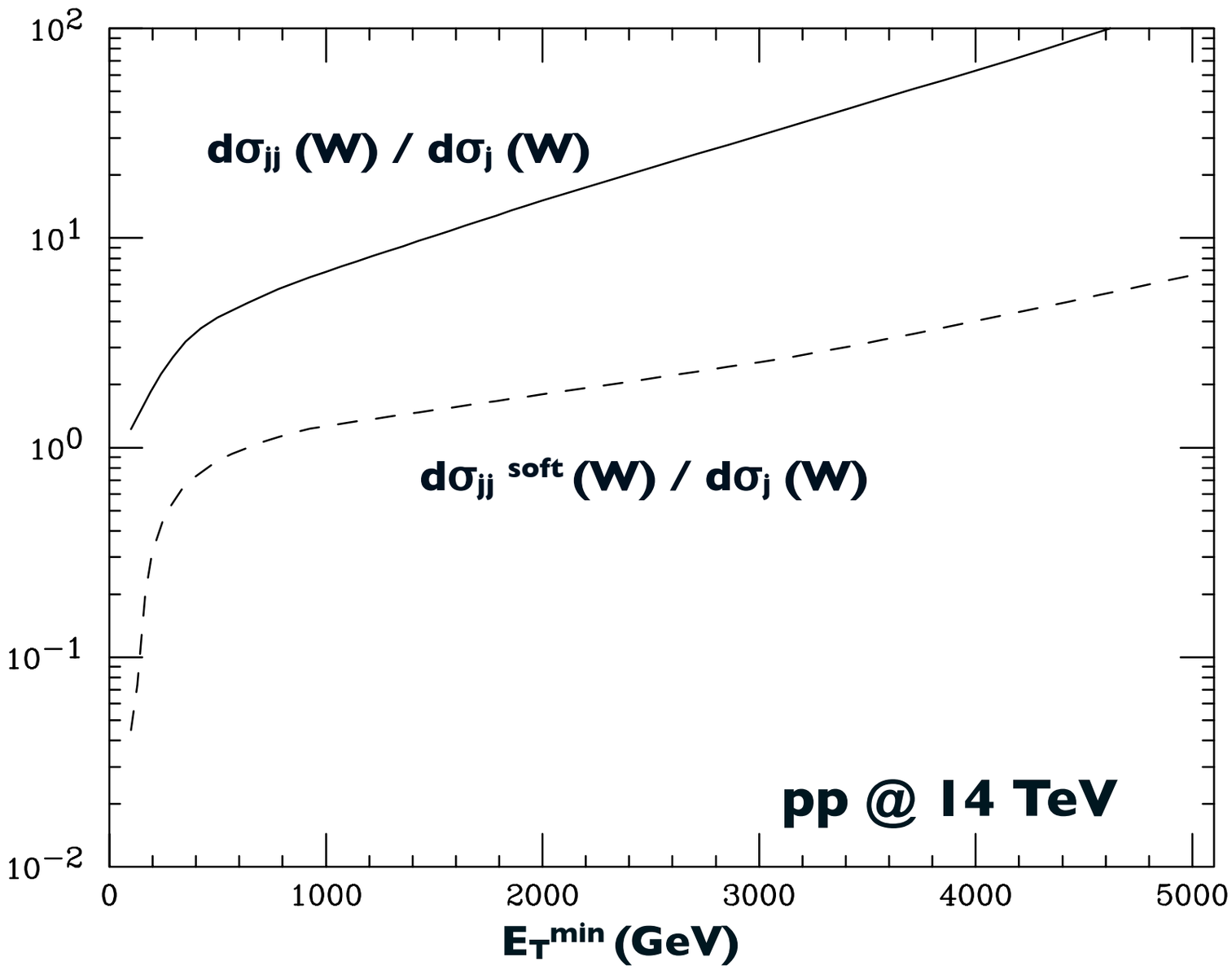
inclusive W production rate, in events with 2 jets of E_T>30 GeV, $|\eta|$<5, with $E_T^{\text{(leading jet)}} > E_T^{\text{min}}$

$d\sigma_{jj}^{\text{soft}}(W)$:

same, with $E_T^{\text{jet 1}} < 0.2 \times E_T^{\text{jet 2}}$

$d\sigma_j(W)$:

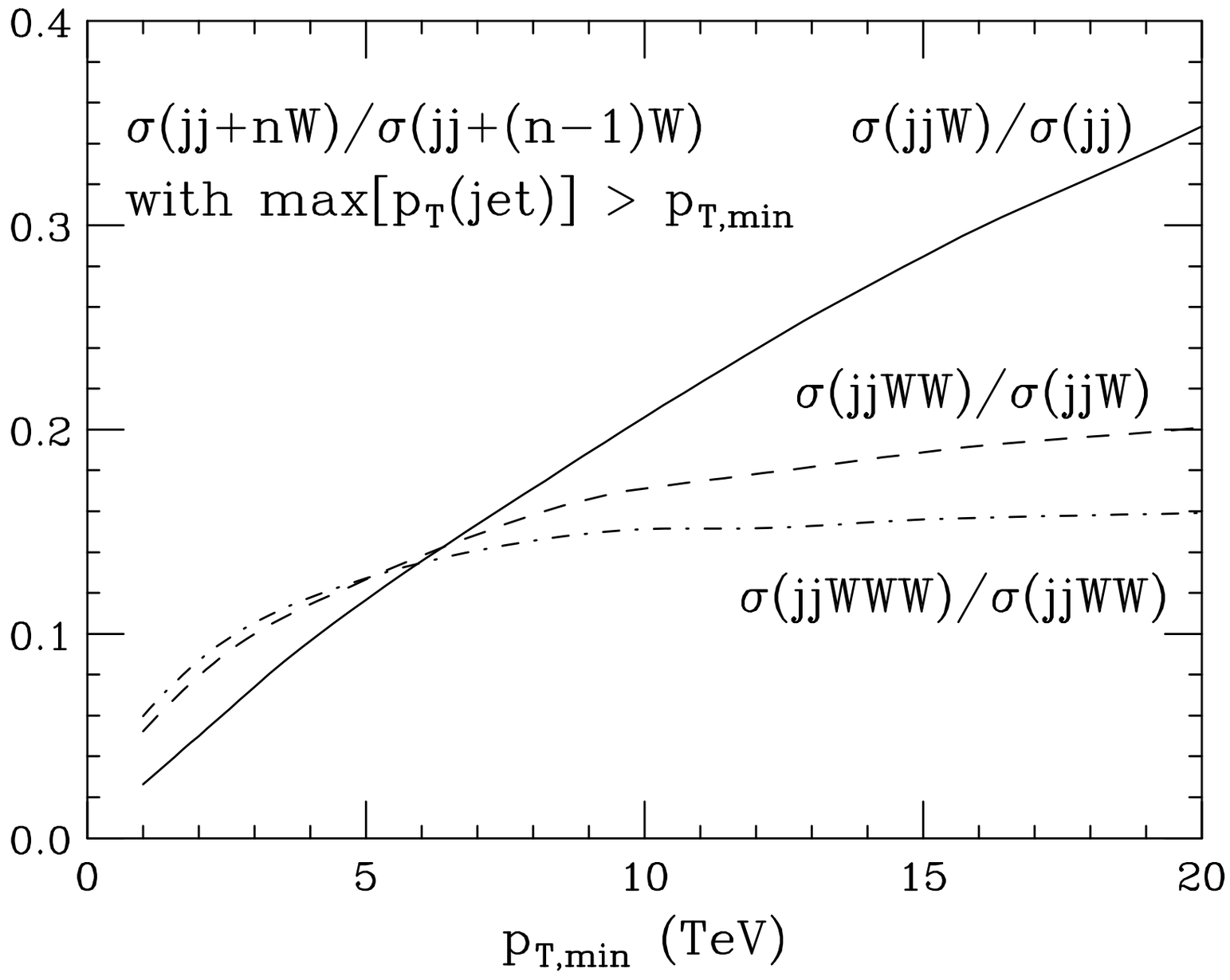
same, with just 1 jet



- $\sigma_j \ll \sigma_{jj} \Rightarrow$ the dynamics is dominated by kinematical configurations other than W+jet

- $\sigma_{jj}^{\text{soft}} \ll \sigma_{jj} \Rightarrow$ the rate is dominated by final states with a second hard jet, so E_T^{min} > 30 GeV protects against large logs

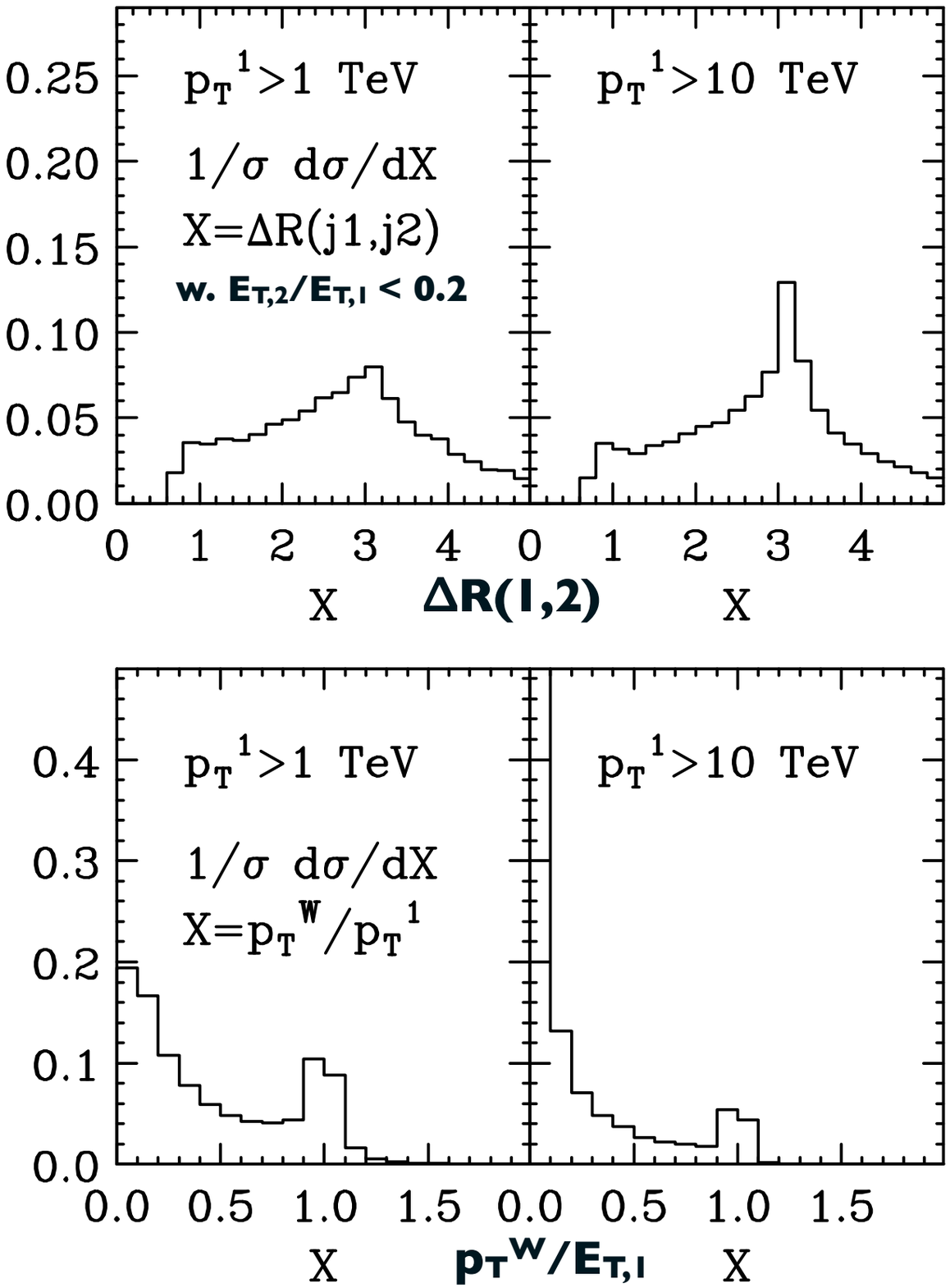
W emission rates from jets

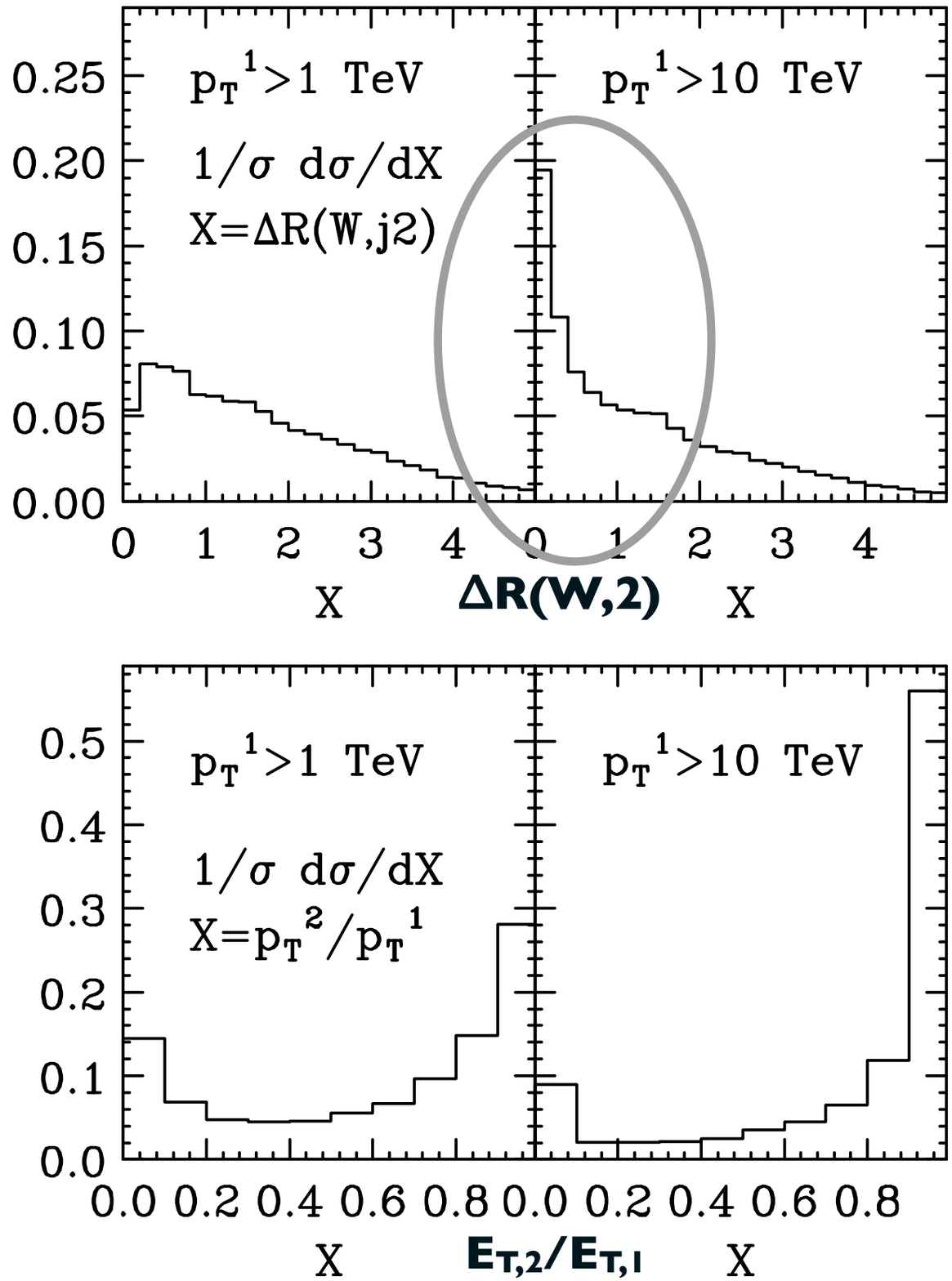


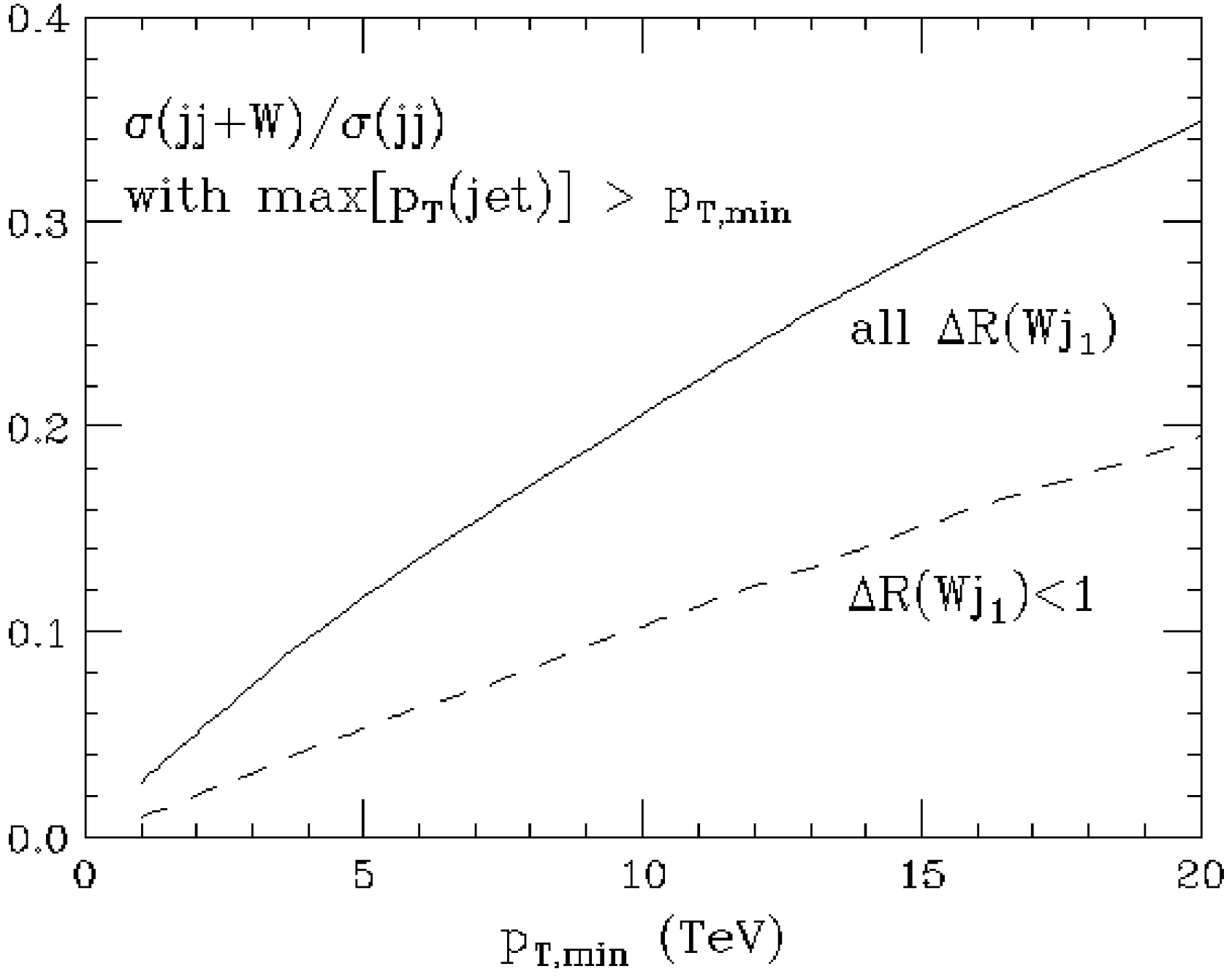
Conclusion: substantial increase of W production at large energy, but W-emission probability small enough that fixed-order PT is likely the most reliable way to model rates and kinematics

W emission distributions

which fraction of Ws can be associated to radiation off the jet, vs ISR or ISR/FSR interference?

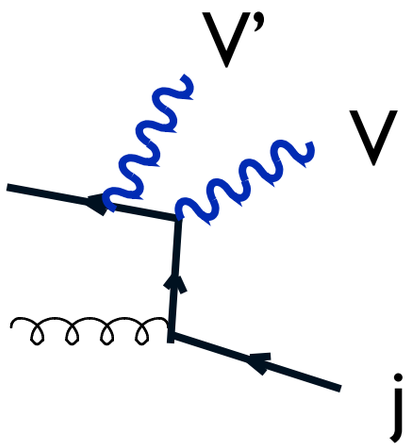




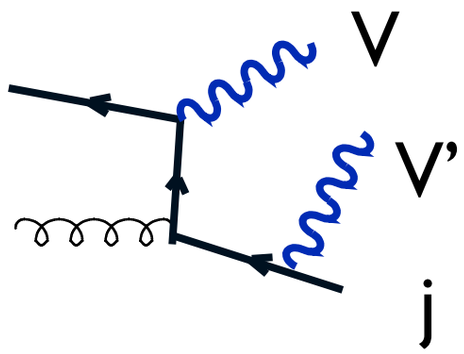

0.4
0.3
0.2
0.1
0.0
0
5
10
15
20
σ(jj+W)/σ(jj)
with max[p_T(jet)] > p_T,min
all ΔR(Wj_1)
ΔR(Wj_1)<1
p_T,min (TeV)

Gauge boson emission from gauge bosons

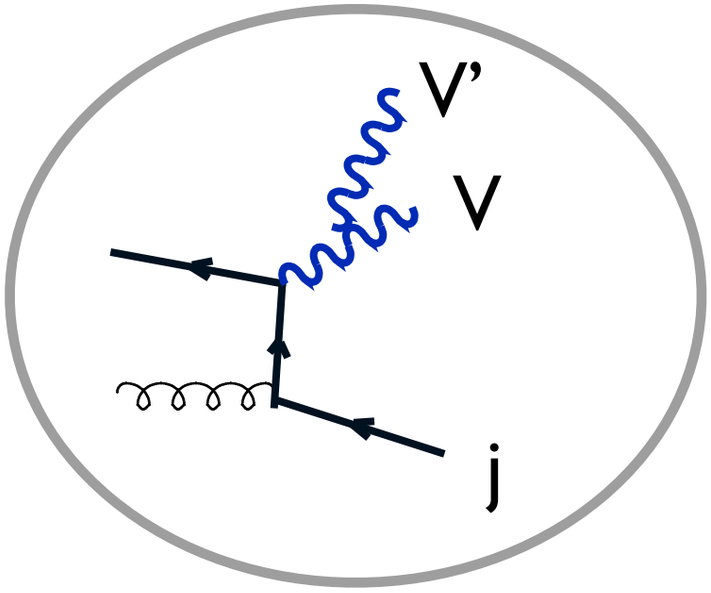
jet + VV‘ vs jet +V



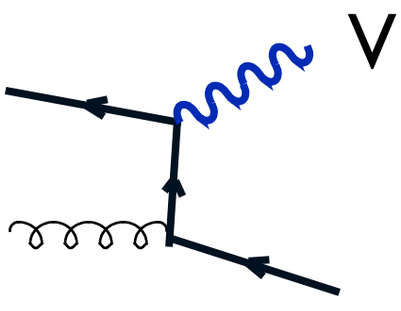
Large logs, fwd V’



Large logs, V’ recoils against V, close to jet

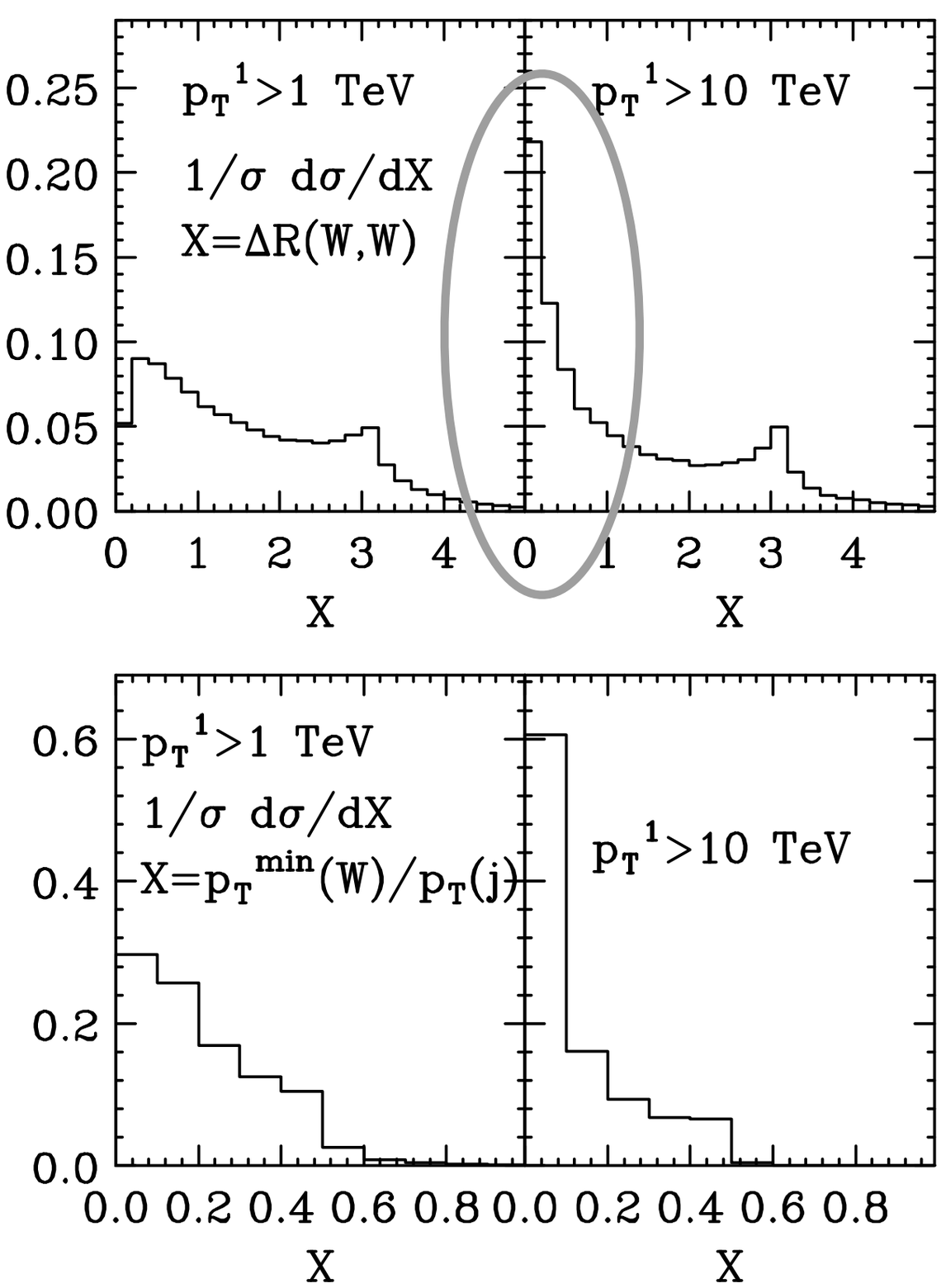


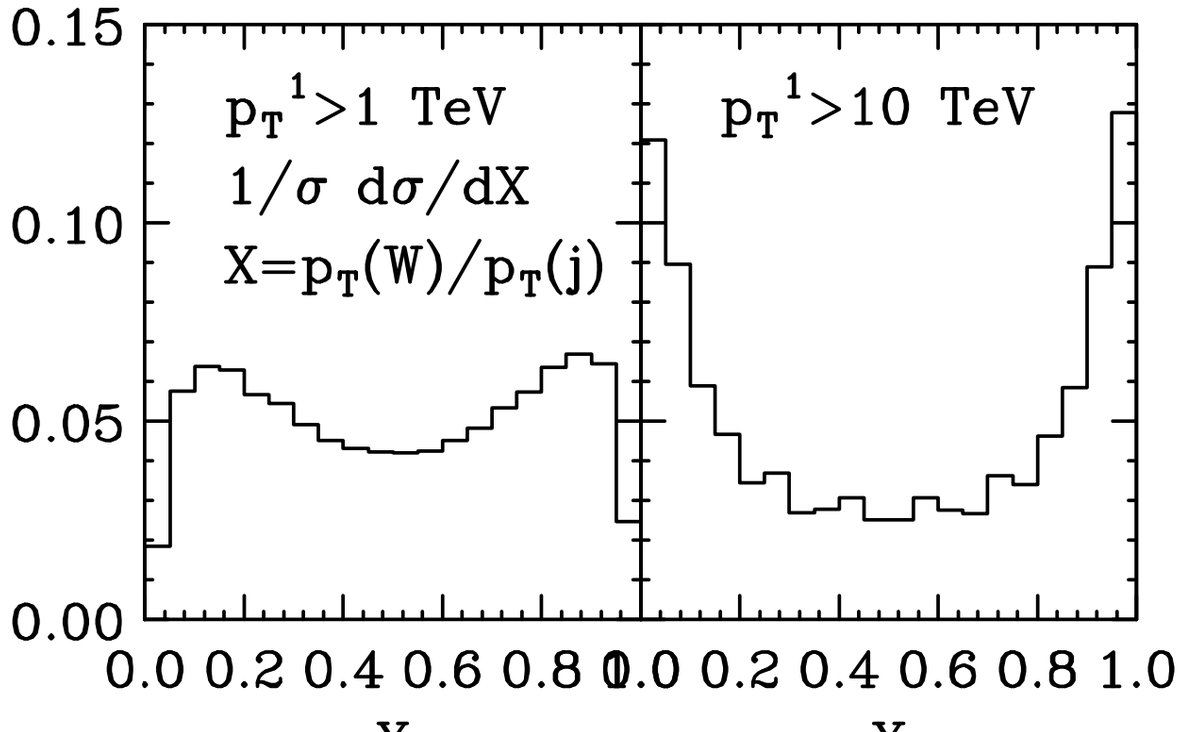
Large logs, V’ close to V



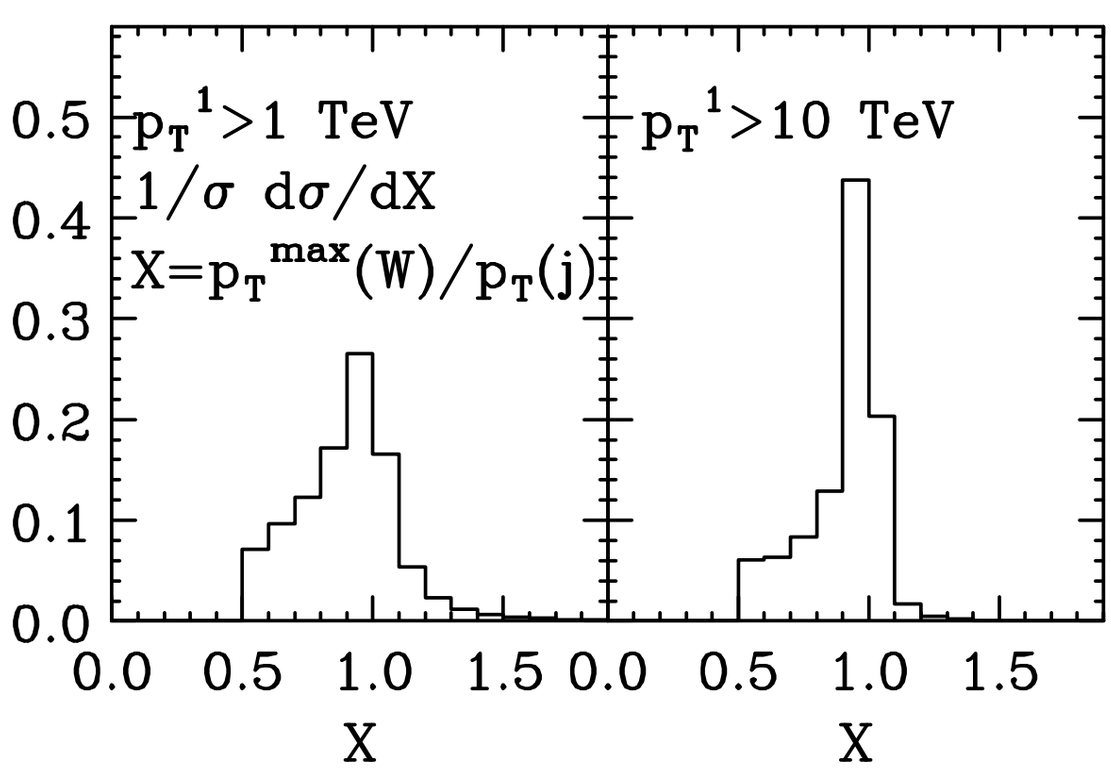
σ(jet+VV’) / σ(jet+V) captures all these 3 contributions (pus interferences, emissions form internal porpagators, ...)

Z-> WW

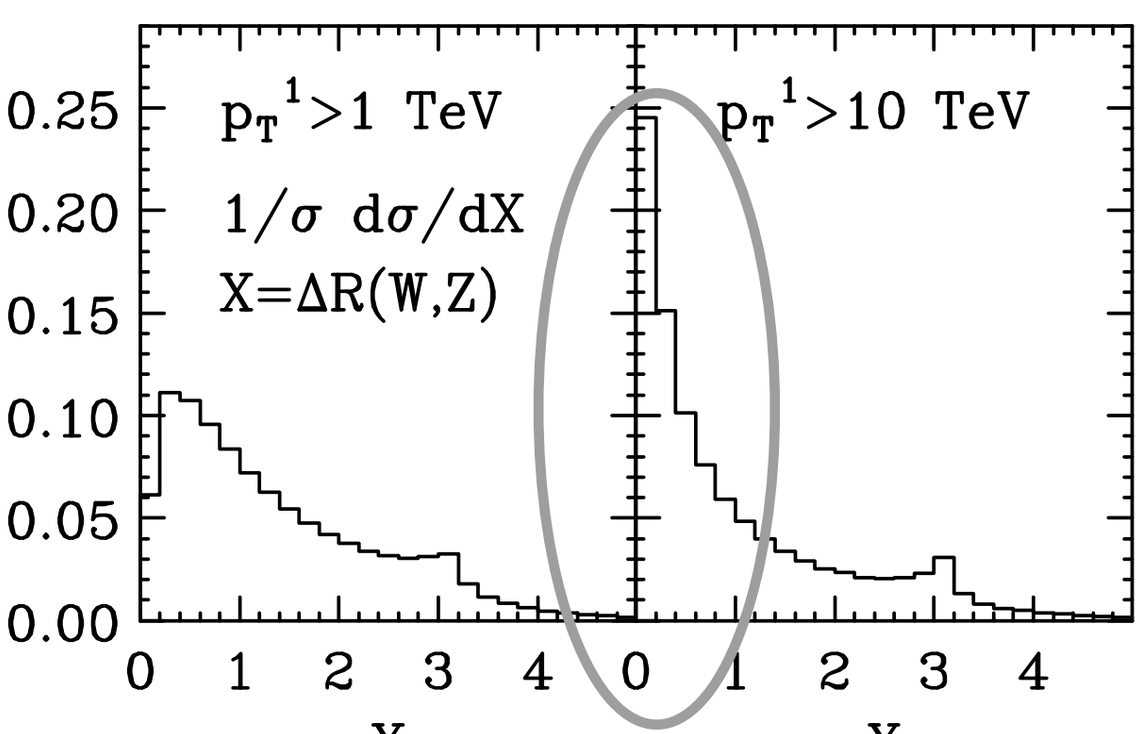

p_T^1>1 TeV
$1/\sigma\ d\sigma/dX$
X=ΔR(W,W)
p_T^1>10 TeV
X
X

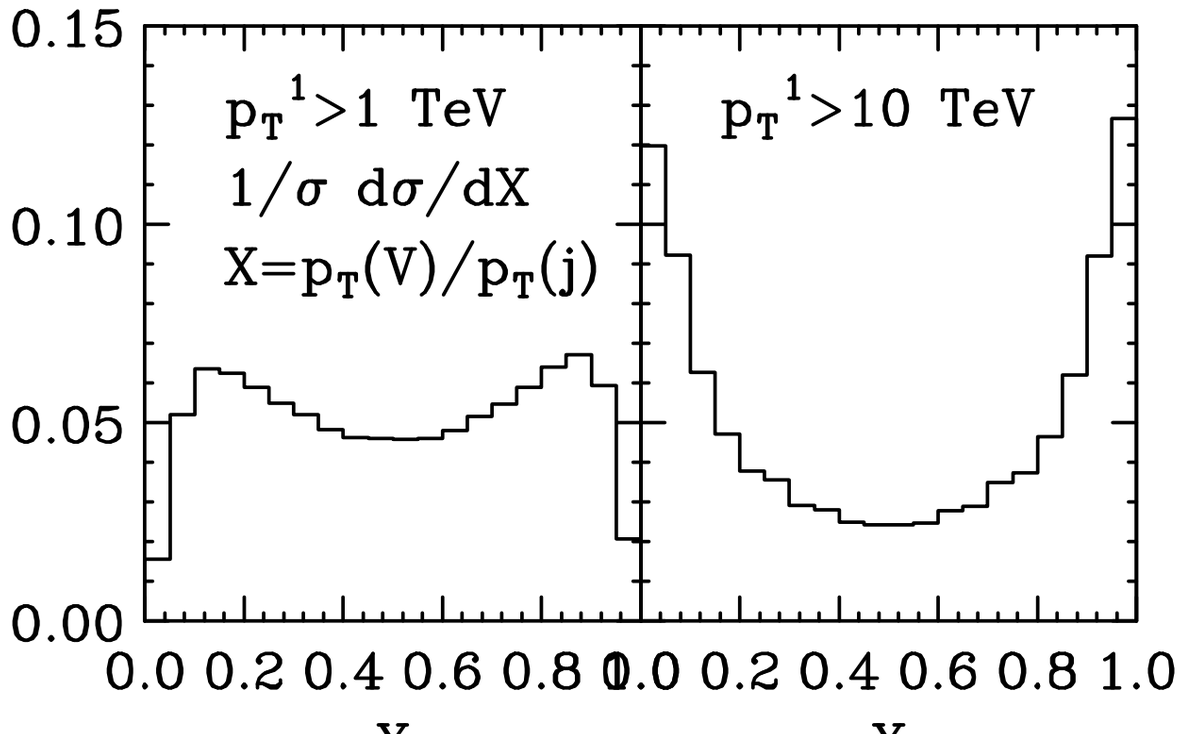

p_T^1>1 TeV
$1/\sigma\ d\sigma/dX$
X=p_T(W)/p_T(j)
p_T^1>10 TeV
X
X

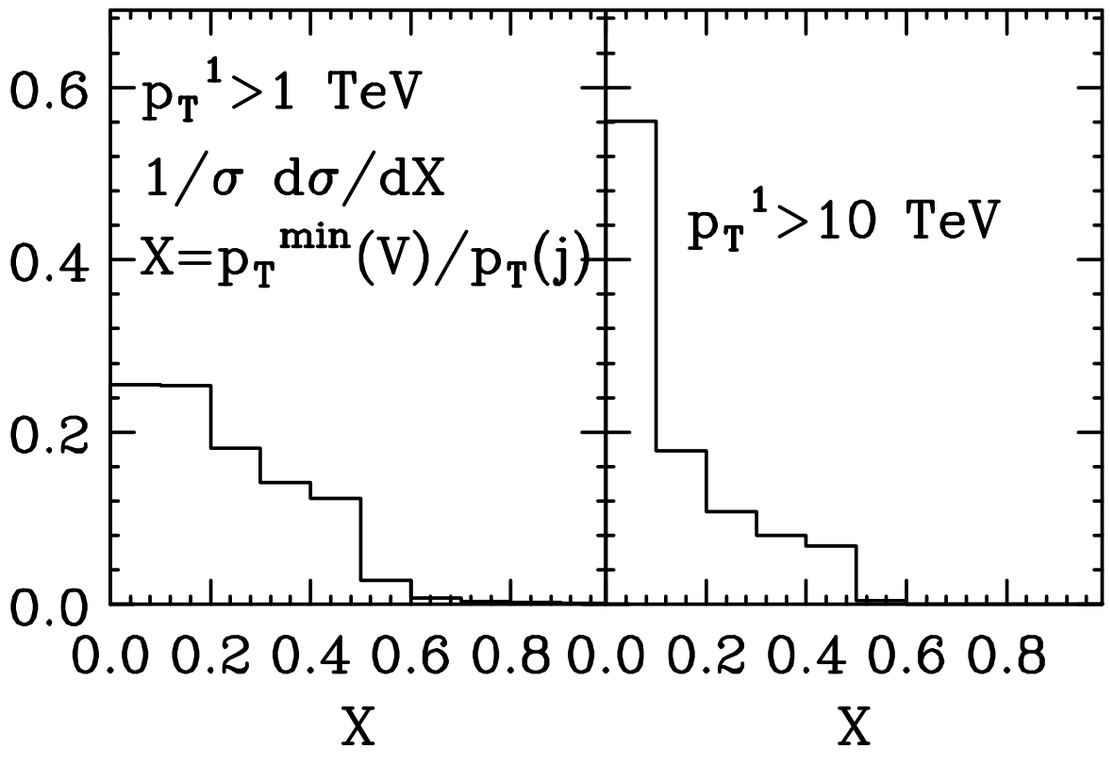
p_T^1>1 TeV
$1/\sigma\ d\sigma/dX$
X=p_T^{min}(W)/p_T(j)
p_T^1>10 TeV
X
X

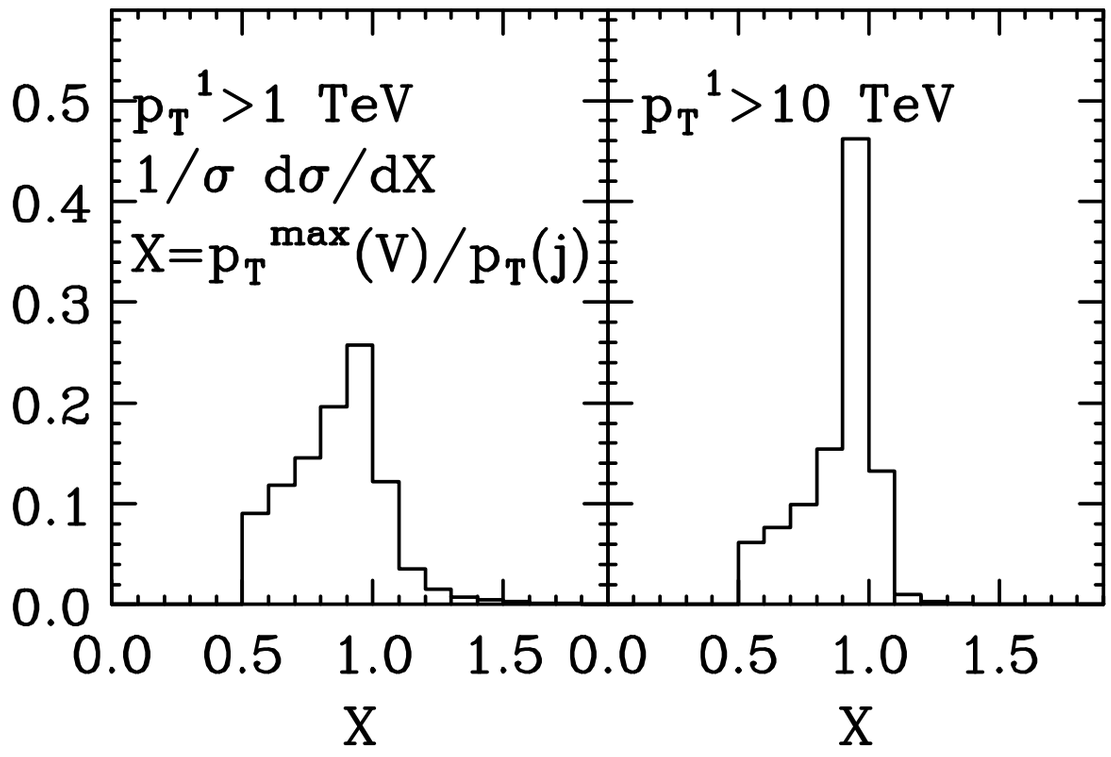

p_T^1>1 TeV
$1/\sigma\ d\sigma/dX$
X=p_T^{max}(W)/p_T(j)
p_T^1>10 TeV
X
X

Z -> WZ


p_T^1>1 TeV
$1/\sigma\ d\sigma/dX$
X=ΔR(W,Z)
p_T^1>10 TeV
X


p_T^1>1 TeV
$1/\sigma\ d\sigma/dX$
X=p_T(V)/p_T(j)
p_T^1>10 TeV
X


p_T^1>1 TeV
$1/\sigma\ d\sigma/dX$
X=p_T^{min}(V)/p_T(j)
p_T^1>10 TeV
X


p_T^1>1 TeV
$1/\sigma\ d\sigma/dX$
X=p_T^{max}(V)/p_T(j)
p_T^1>10 TeV
X

W/Z emission rates from W/Z