Matching Matrix Elements and Parton Showers

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- Status
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- Conclusions

Introduction

- Parton Shower (PS) simulations use the soft/collinear approximation:
  - Good for simulating the internal structure of a jet;
  - Can't produce high p_T jets.
- Matrix Elements (ME) compute the exact result at fixed order:
  - Good for simulating many high p_T jets;
  - Can't give the structure of a jet.
- We want to use both in a consistent way, *i.e.*
  - ME gives hard emission,
  - PS gives soft/collinear emission,
  - Smooth matching between the two,
  - No double counting of radiation.

Procedure

- In order to achieve this we need to separate the phase space:
  - One region should contain the soft/collinear region and be filled by the PS;
  - The other is filled by the matrix element.

- In Catani-Krauss-Webber (CKW) prescription this is done via the Durham jet algorithm.
  - For all final-state particles compute the resolution variables
    * $d_{kB} \simeq E_k^2\theta_{kB}^2 \simeq k_{\perp kB}^2, \quad \theta_{kB} \to 0.$
    * $d_{kl} \simeq \min(E_k^2, E_l^2)\theta_{kl}^2, \quad \theta_{kl} \to 0$
  - The smallest of these d_{kB}, d_{kl} is then selected. If d_{ij} is the smallest the two particles are merged, if d_{iB} is the smallest the particle is merged with the beam.
  - This procedure is repeated until the minimum value is above some stopping parameter d_{cut}.
  - The remaining particles and pseudo-particles are then the hard jets.

Procedure

1. Select the jet multiplicity with probability

$$P_n = \frac{\sigma_n}{\sum_{k=0}^{k=N} \sigma_k}$$

   where σ_n is the n-jet matrix element evaluated at resolution $d_{\rm ini}$ using $d_{\rm ini}$ as the scale for the P.D.F's and α_S.

2. Distribute the jet momenta according to the ME.

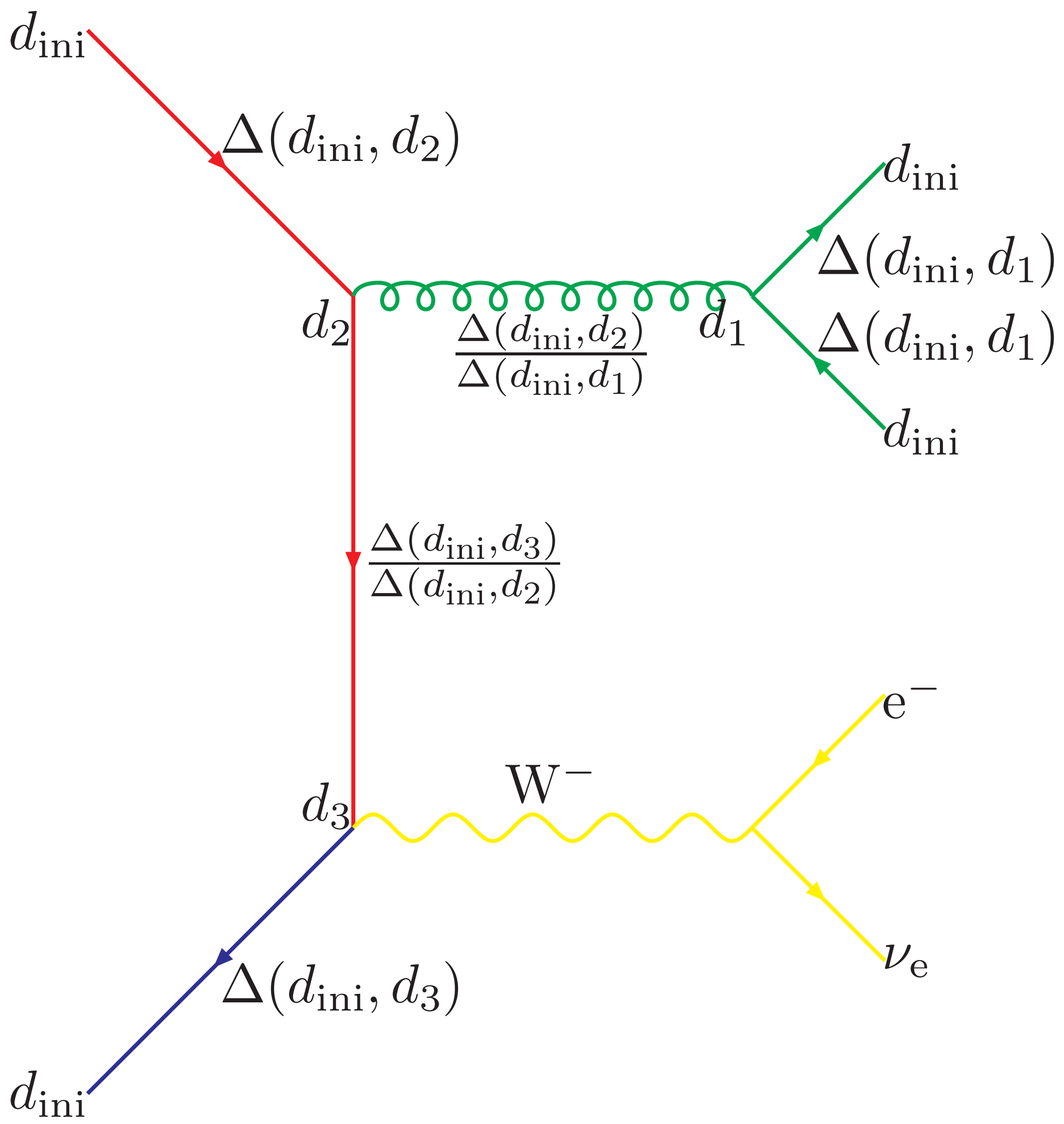
3. Cluster the partons to determine the values at which 1,2,..n-jets are resolved. These give the nodal scales for a tree diagram.

4. Apply a coupling-constant reweighting $\alpha_S(d_1)\alpha_S(d_2)..\alpha_S(d_n)/(\alpha_S(d_{\rm ini})^n \leq 1$.

5. Reweight the lines by a Sudakov factor $\Delta(d_{\rm ini}, d_j)/\Delta(d_{\rm ini}, d_k)$.

6. Accept the configuration if the product of the α_S and Sudakov weight is less the $\mathcal{R} \in [0,1]$., otherwise return to step 1.

Procedure



7. Generate the parton shower from the event starting the evolution of each parton at the scale it was created and vetoing emission above the scale d_{ini}

Status

- We have a number of matrix element generators generating events in the Les Houches format.

- At the Durham Workshop we decided that the existing event generators could be easily modified to use the CKW prescription with Les Houches events.

- The basic idea is that there will be minimal changes to HERWIG (or PYTHIA).

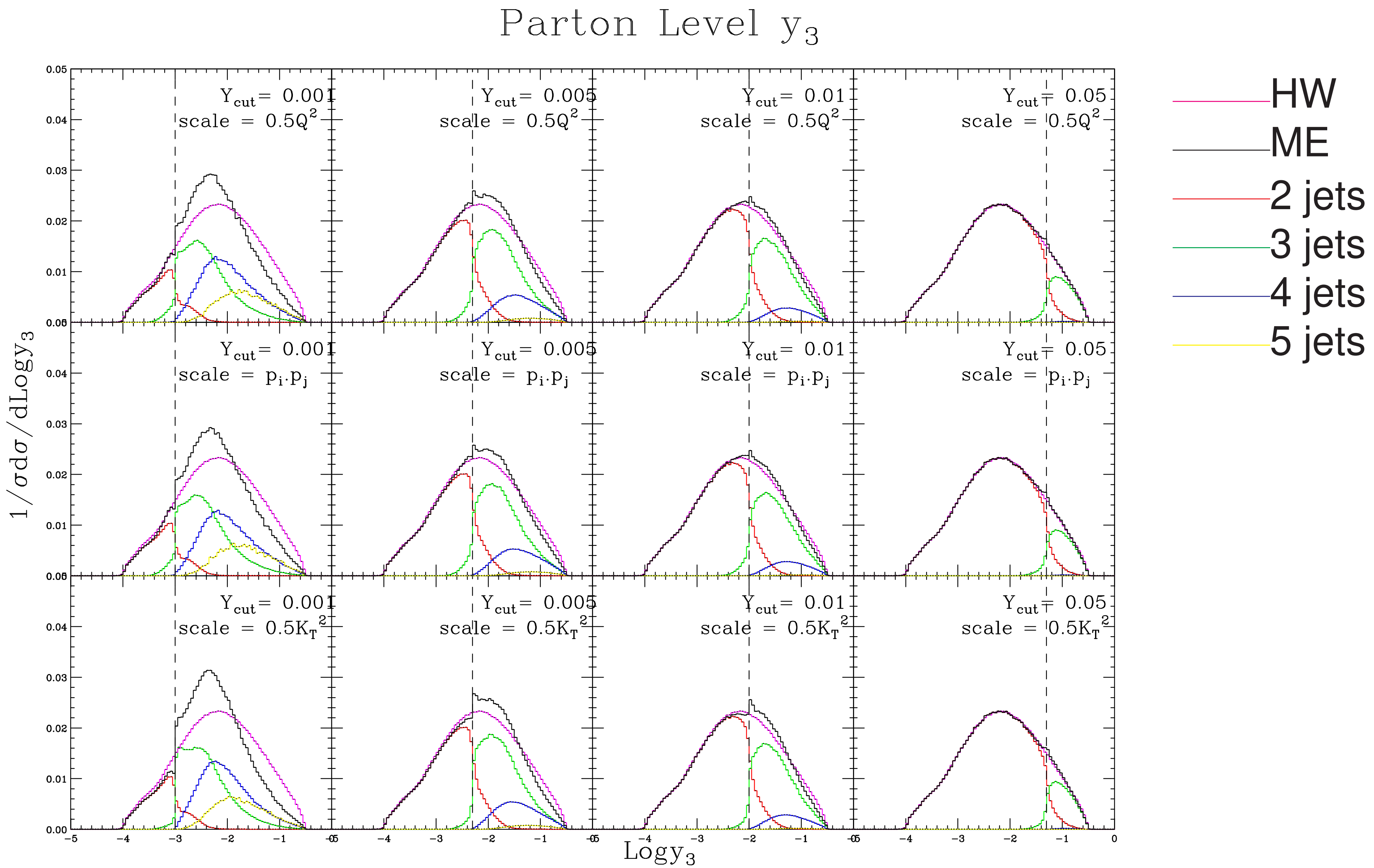
- The reweighting, clustering etc. will be handled by a separate piece of code to read in the Les Houches events.

- Steve Mrenna is working on something for PYTHIA

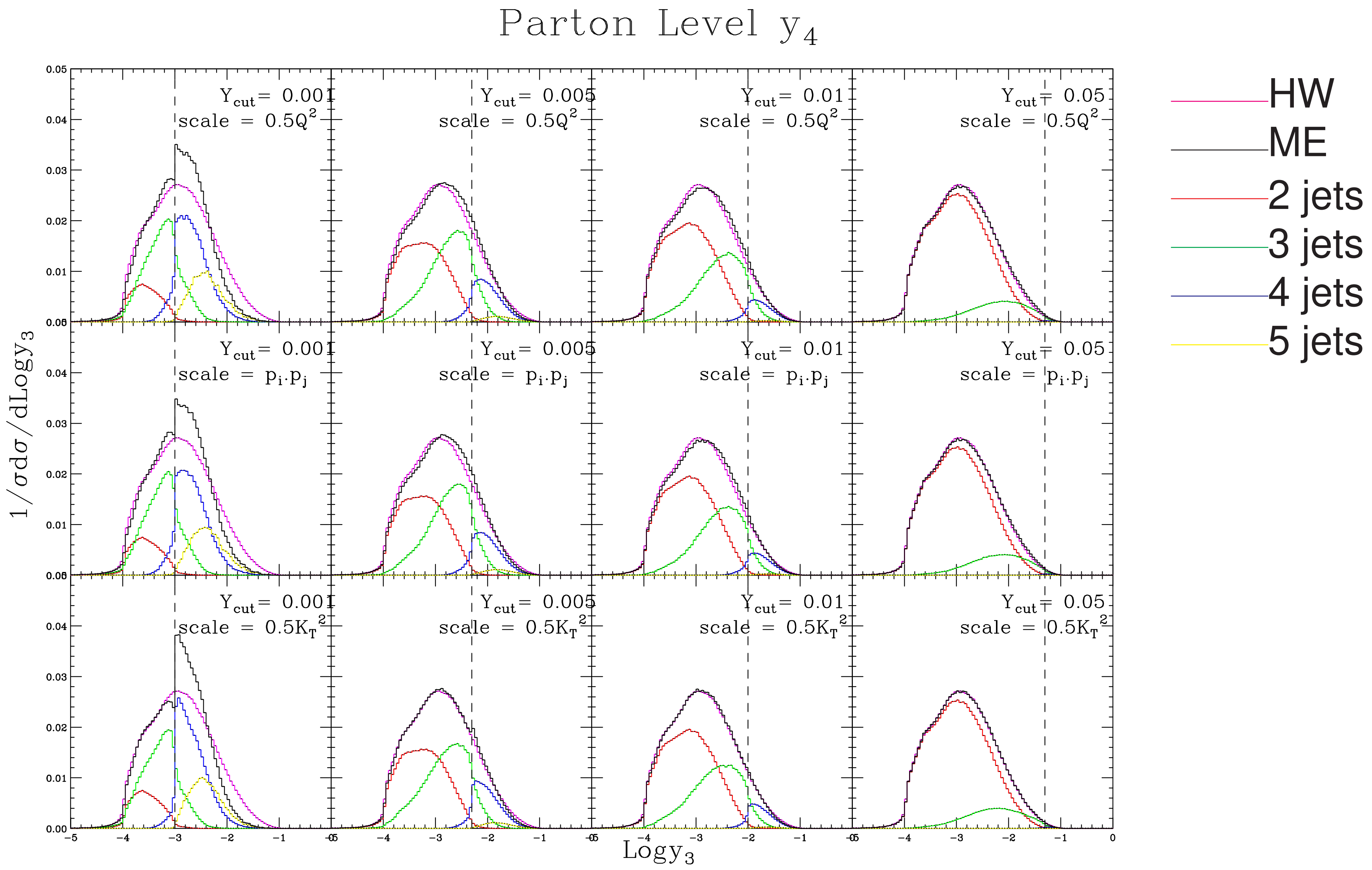
- I'm working on something for HERWIG.

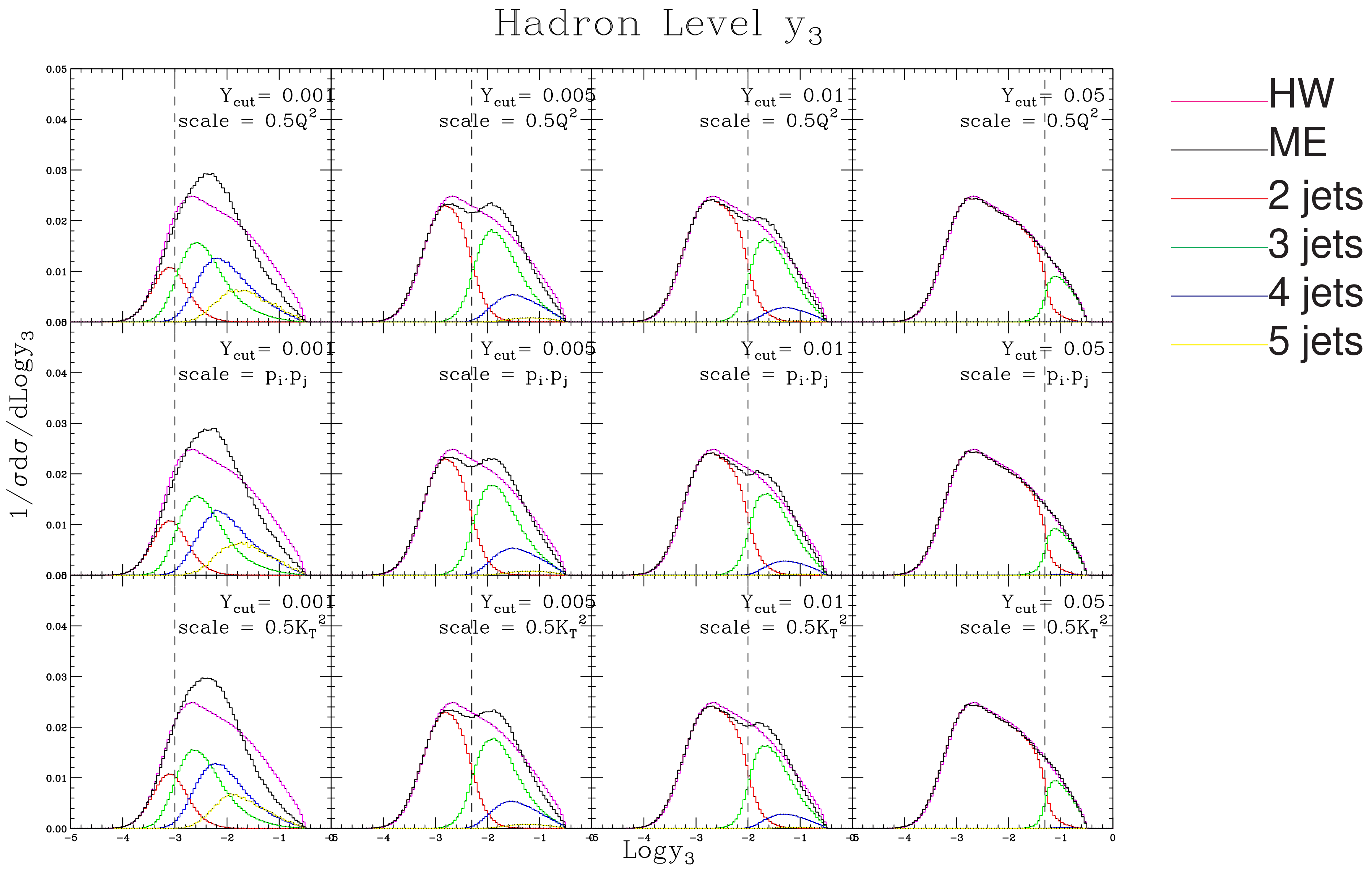
Results

- I will present results from HERWIG
  - $\mathrm{e^+e^-} \to \mathrm{jets}$
  - $\mathrm{p\bar{p}} \to \mathrm{W} + \mathrm{jets}$
- These results are very preliminary.
- In the $\mathrm{e^+e^-}$ results $y = d/s$.

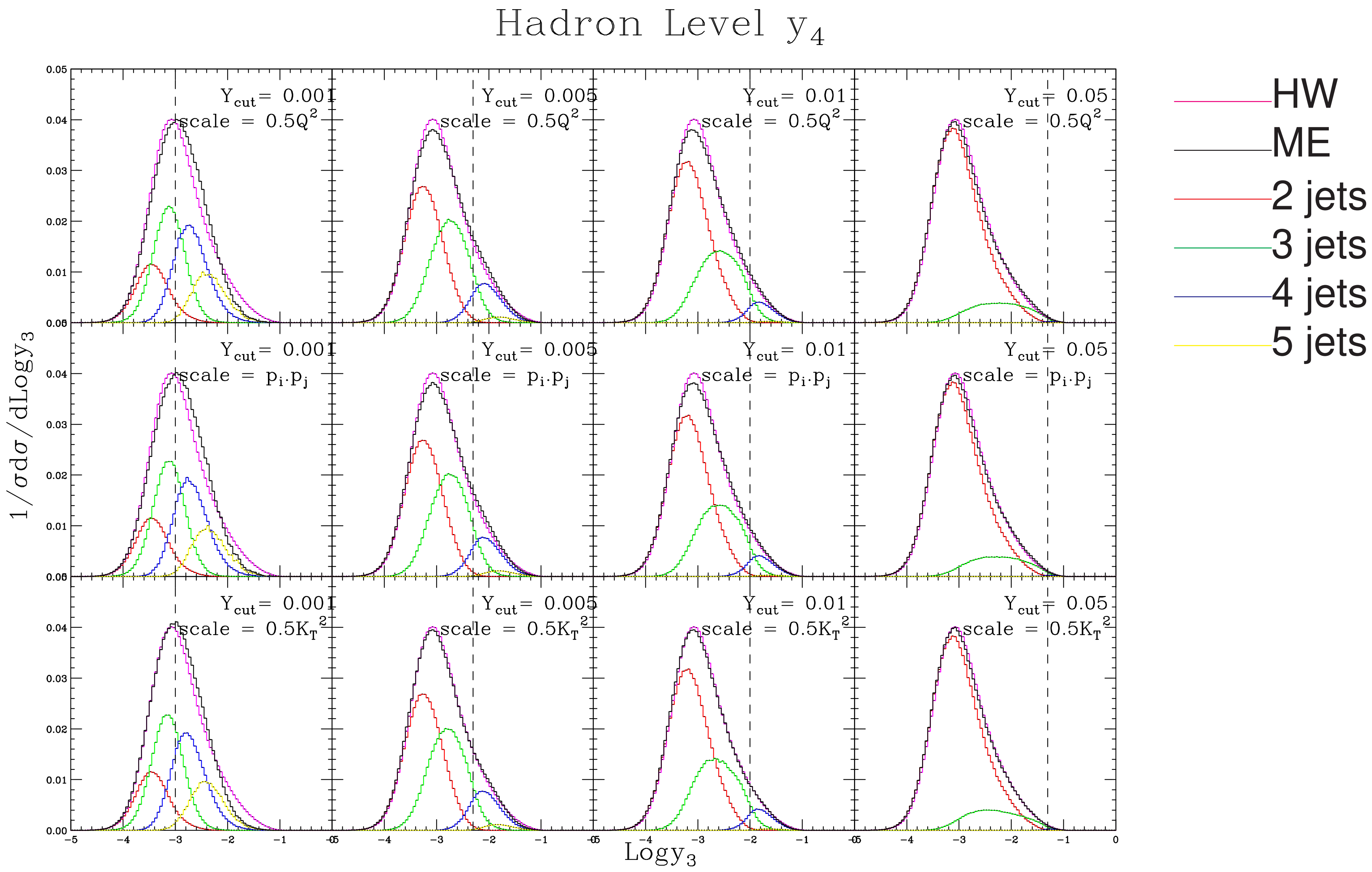


Parton Level y_3
$1/\sigma d\sigma/dLogy_3$
Logy$_3$
Y_{cut} = 0.001
scale = $0.5Q^2$
Y_{cut} = 0.005
scale = $0.5Q^2$
Y_{cut} = 0.01
scale = $0.5Q^2$
Y_{cut} = 0.05
scale = $0.5Q^2$
Y_{cut} = 0.001
scale = $p_i.p_j$
Y_{cut} = 0.005
scale = $p_i.p_j$
Y_{cut} = 0.01
scale = $p_i.p_j$
Y_{cut} = 0.05
scale = $p_i.p_j$
Y_{cut} = 0.001
scale = $0.5K_T^2$
Y_{cut} = 0.005
scale = $0.5K_T^2$
Y_{cut} = 0.01
scale = $0.5K_T^2$
Y_{cut} = 0.05
scale = $0.5K_T^2$
HW
ME
2 jets
3 jets
4 jets
5 jets

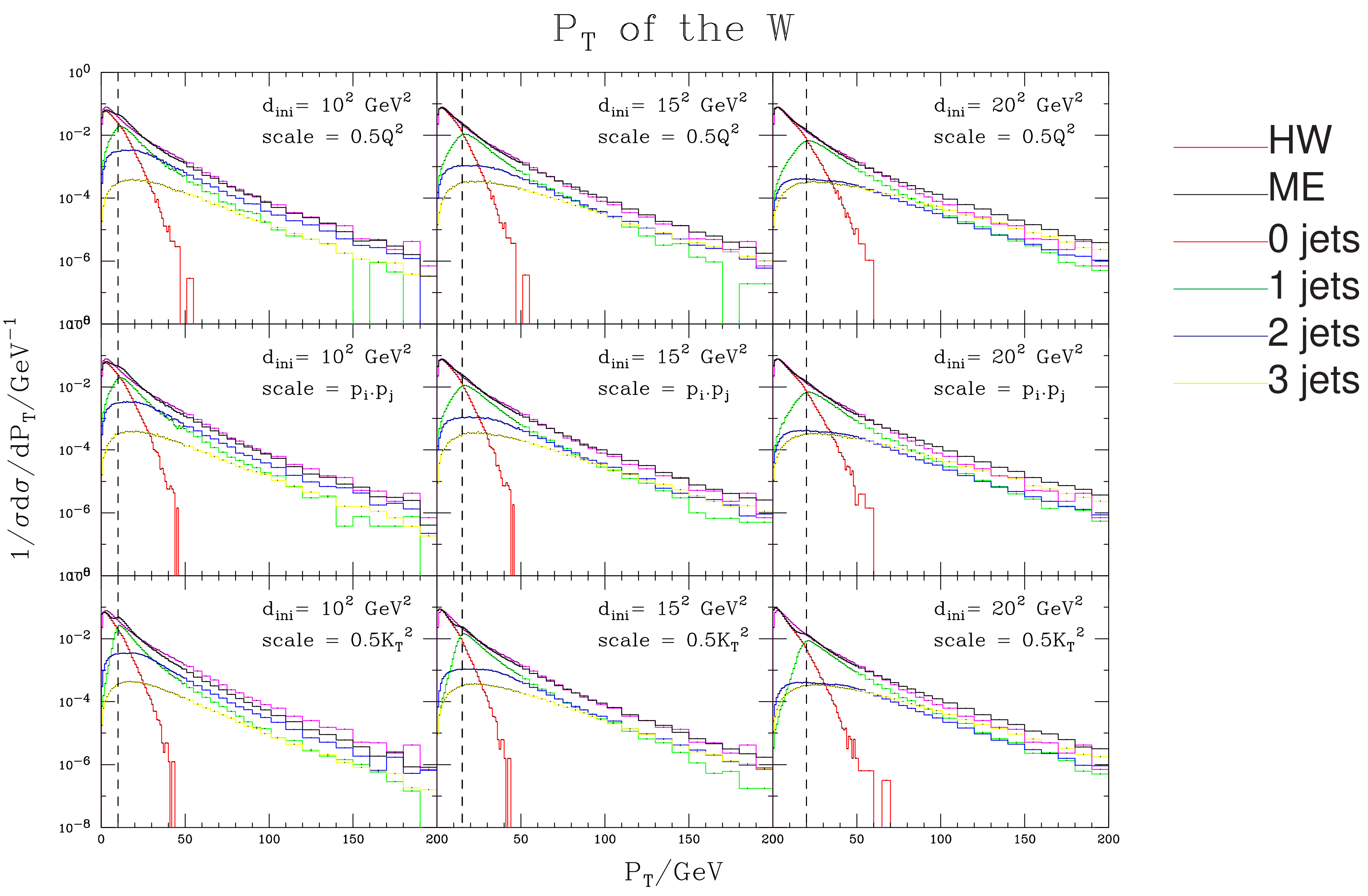

Parton Level y_4
$1/\sigma d\sigma/d\mathrm{Log}y_3$
$\mathrm{Log}y_3$
Y_{cut} = 0.001
scale = $0.5Q^2$
Y_{cut} = 0.005
Y_{cut} = 0.01
Y_{cut} = 0.05
scale = $p_i.p_j$
scale = $0.5K_T^2$
HW
ME
2 jets
3 jets
4 jets
5 jets



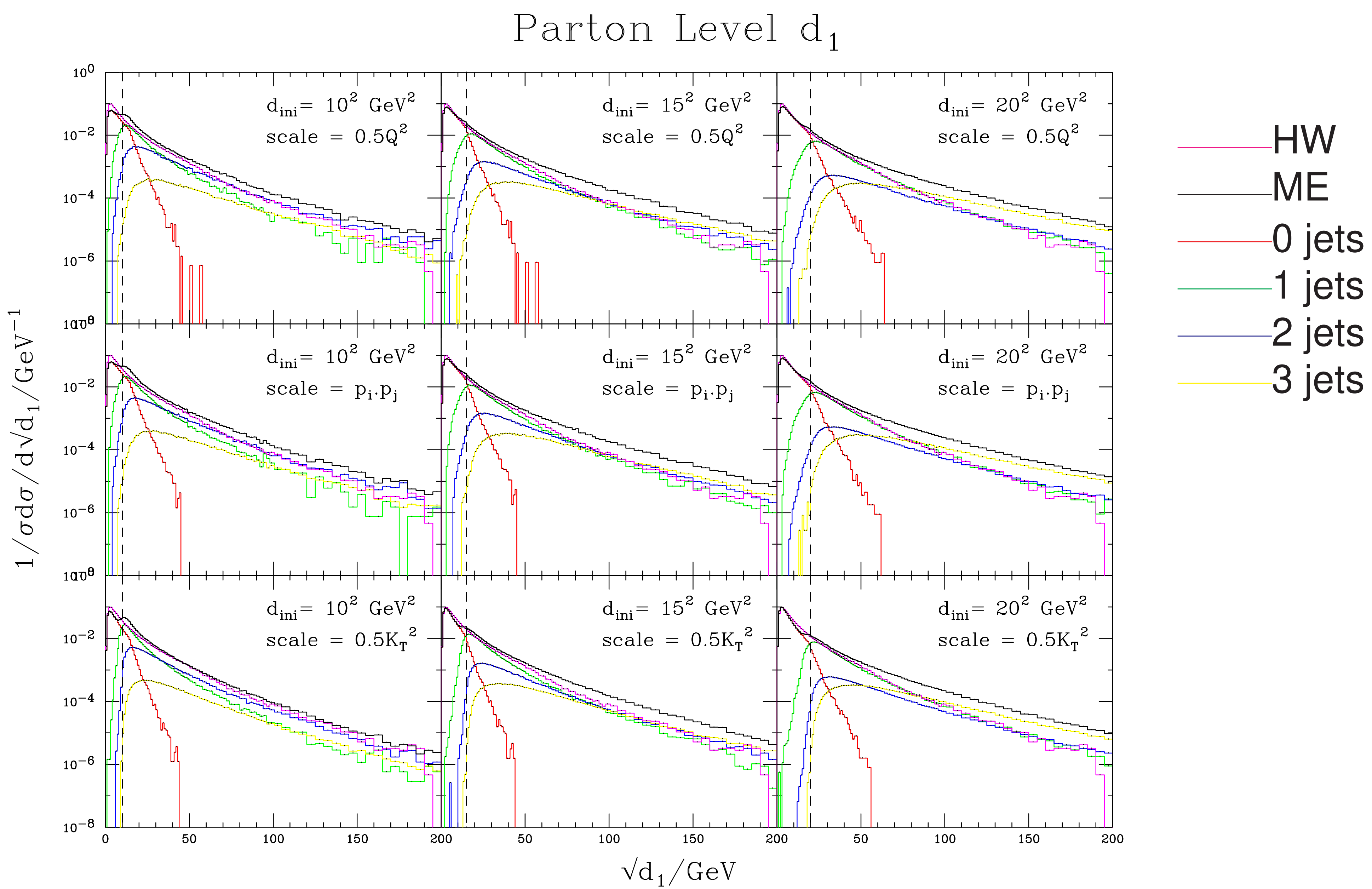
Hadron Level y_3
Y_{cut} = 0.001
scale = $0.5Q^2$
Y_{cut} = 0.005
Y_{cut} = 0.01
Y_{cut} = 0.05
scale = $p_i.p_j$
scale = $0.5K_T^2$
$1/\sigma d\sigma/dLogy_3$
$Logy_3$
HW
ME
2 jets
3 jets
4 jets
5 jets

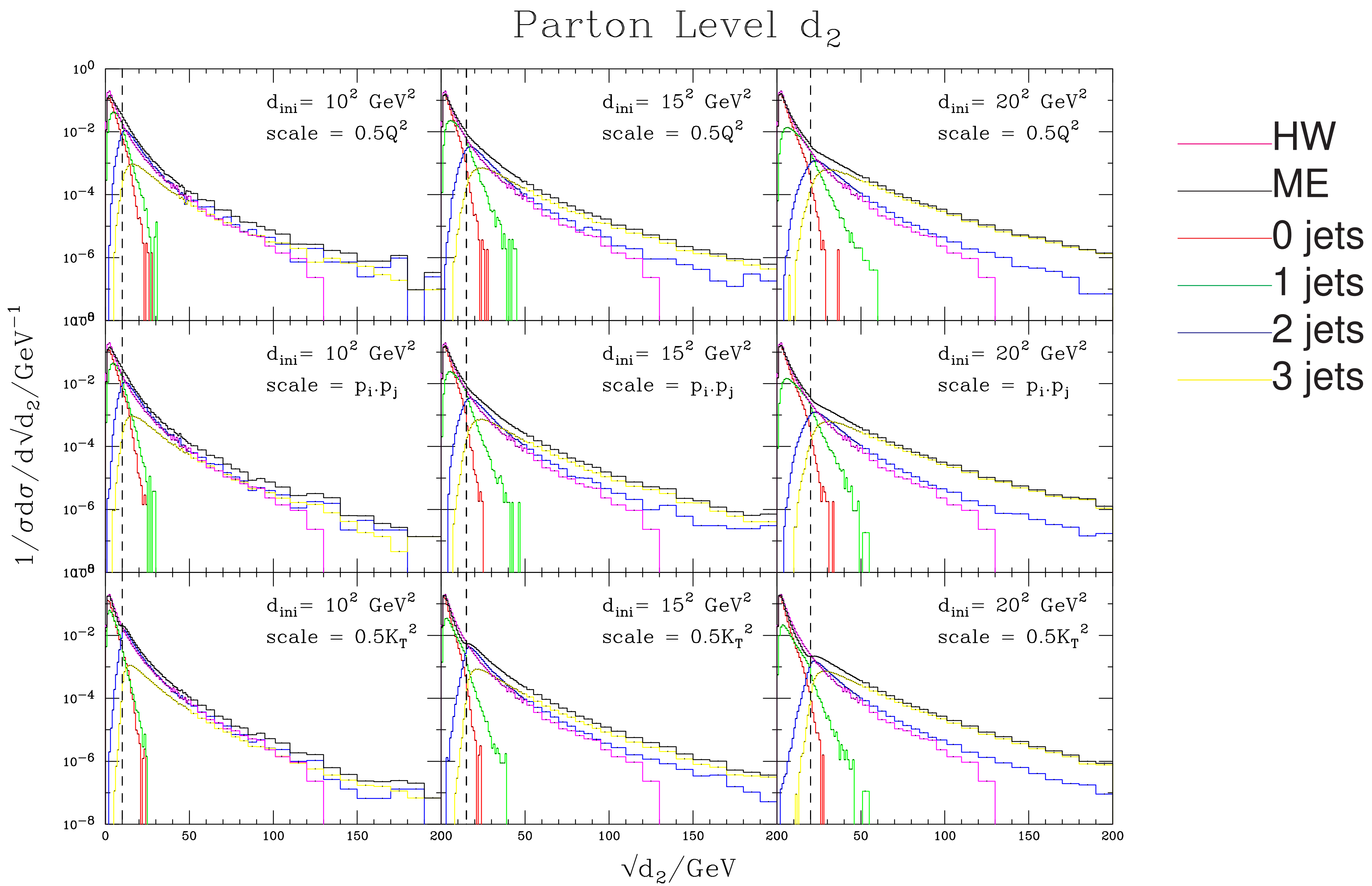


Hadron Level y_4
HW
ME
2 jets
3 jets
4 jets
5 jets
Y_{cut} = 0.001
Y_{cut} = 0.005
Y_{cut} = 0.01
Y_{cut} = 0.05
scale = $0.5Q^2$
scale = $p_i \cdot p_j$
scale = $0.5K_T{}^2$
$1/\sigma d\sigma/dLogy_3$
$Logy_3$

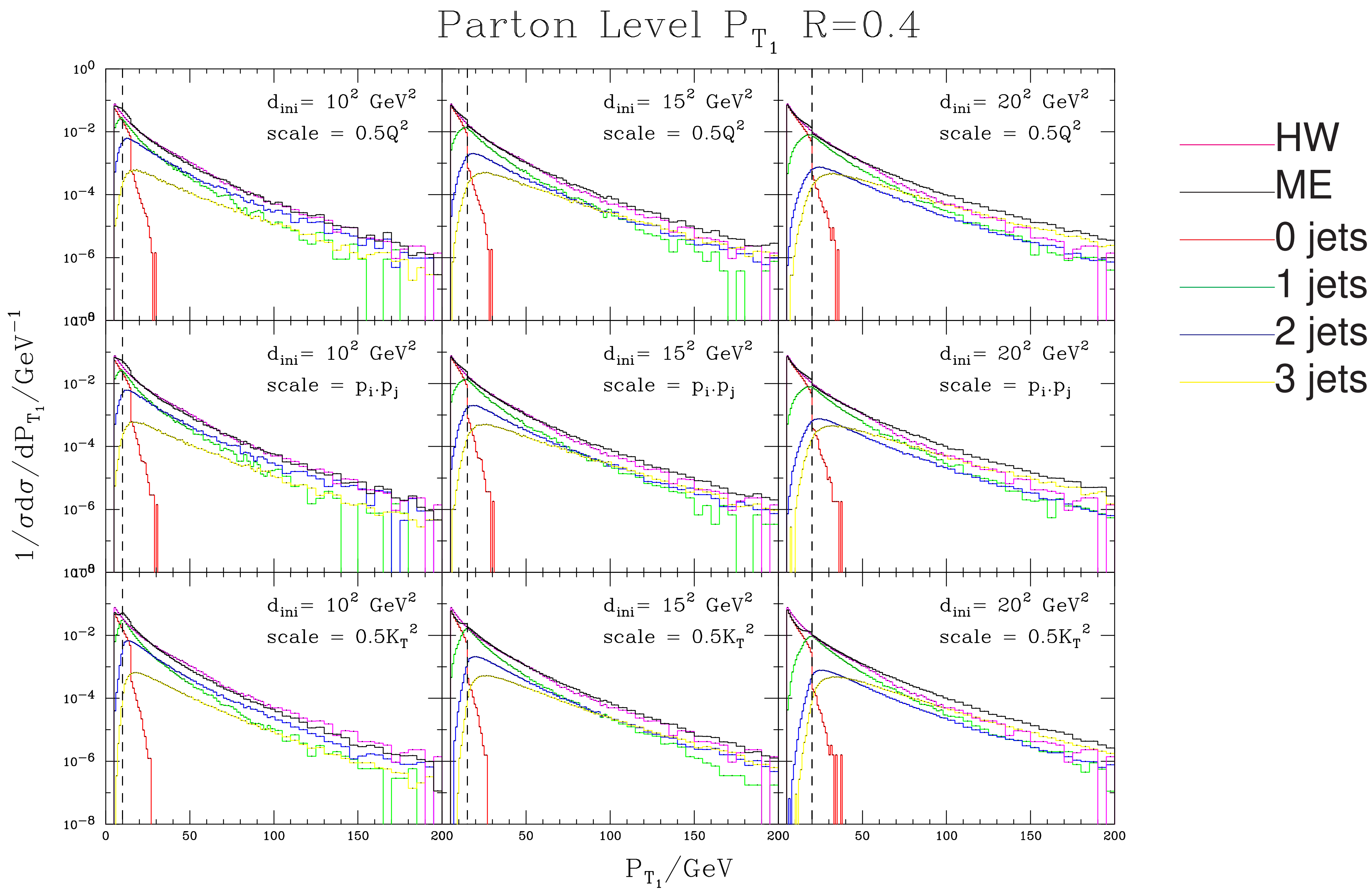


P_T of the W
d_ini= 10^2 GeV^2
scale = 0.5Q^2
d_ini= 15^2 GeV^2
scale = 0.5Q^2
d_ini= 20^2 GeV^2
scale = 0.5Q^2
d_ini= 10^2 GeV^2
scale = p_i.p_j
d_ini= 15^2 GeV^2
scale = p_i.p_j
d_ini= 20^2 GeV^2
scale = p_i.p_j
d_ini= 10^2 GeV^2
scale = 0.5K_T^2
d_ini= 15^2 GeV^2
scale = 0.5K_T^2
d_ini= 20^2 GeV^2
scale = 0.5K_T^2
HW
ME
0 jets
1 jets
2 jets
3 jets
1/σdσ/dP_T/GeV^-1
P_T/GeV

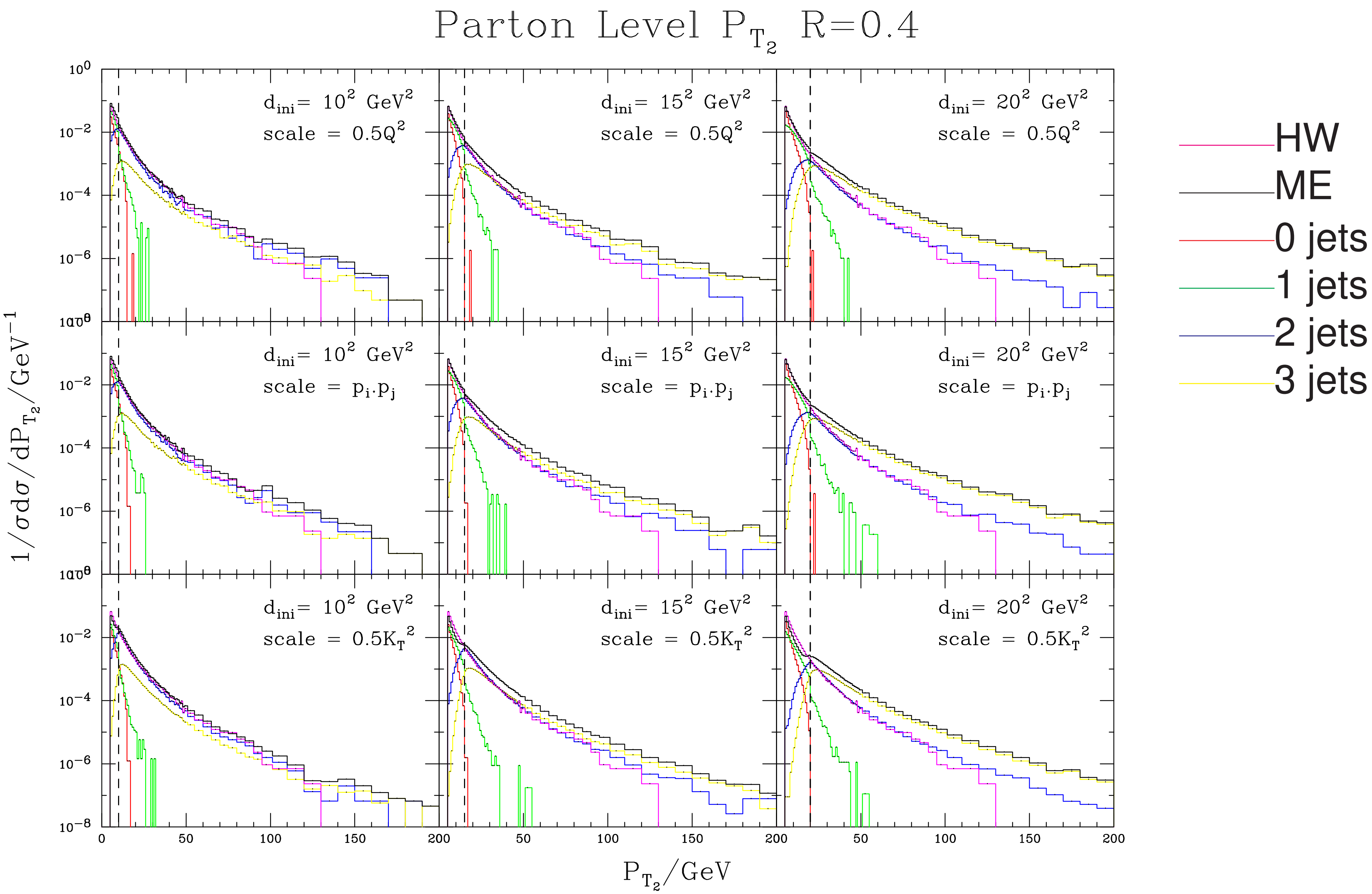

Parton Level d_1
$d_{ini} = 10^2$ GeV^2
scale = $0.5Q^2$
$d_{ini} = 15^2$ GeV^2
$d_{ini} = 20^2$ GeV^2
scale = $p_i \cdot p_j$
scale = $0.5K_T^2$
$1/\sigma d\sigma/d\sqrt{d_1}$/GeV^{-1}
$\sqrt{d_1}$/GeV
HW
ME
0 jets
1 jets
2 jets
3 jets



Parton Level d_2
$d_{ini} = 10^2$ GeV^2
scale = $0.5Q^2$
$d_{ini} = 15^2$ GeV^2
scale = $0.5Q^2$
$d_{ini} = 20^2$ GeV^2
scale = $0.5Q^2$
$d_{ini} = 10^2$ GeV^2
scale = $p_i \cdot p_j$
$d_{ini} = 15^2$ GeV^2
scale = $p_i \cdot p_j$
$d_{ini} = 20^2$ GeV^2
scale = $p_i \cdot p_j$
$d_{ini} = 10^2$ GeV^2
scale = $0.5K_T{}^2$
$d_{ini} = 15^2$ GeV^2
scale = $0.5K_T{}^2$
$d_{ini} = 20^2$ GeV^2
scale = $0.5K_T{}^2$
$1/\sigma d\sigma/d\sqrt{d_2}$/GeV^{-1}
$\sqrt{d_2}$/GeV
HW
ME
0 jets
1 jets
2 jets
3 jets



Parton Level P_{T_1} R=0.4
d_{ini}= 10^2 GeV^2
scale = $0.5Q^2$
d_{ini}= 15^2 GeV^2
scale = $0.5Q^2$
d_{ini}= 20^2 GeV^2
scale = $0.5Q^2$
d_{ini}= 10^2 GeV^2
scale = $p_i.p_j$
d_{ini}= 15^2 GeV^2
scale = $p_i.p_j$
d_{ini}= 20^2 GeV^2
scale = $p_i.p_j$
d_{ini}= 10^2 GeV^2
scale = $0.5K_T^2$
d_{ini}= 15^2 GeV^2
scale = $0.5K_T^2$
d_{ini}= 20^2 GeV^2
scale = $0.5K_T^2$
$1/\sigma d\sigma/dP_{T_1}/GeV^{-1}$
P_{T_1}/GeV
HW
ME
0 jets
1 jets
2 jets
3 jets


Parton Level P_{T_2} R=0.4
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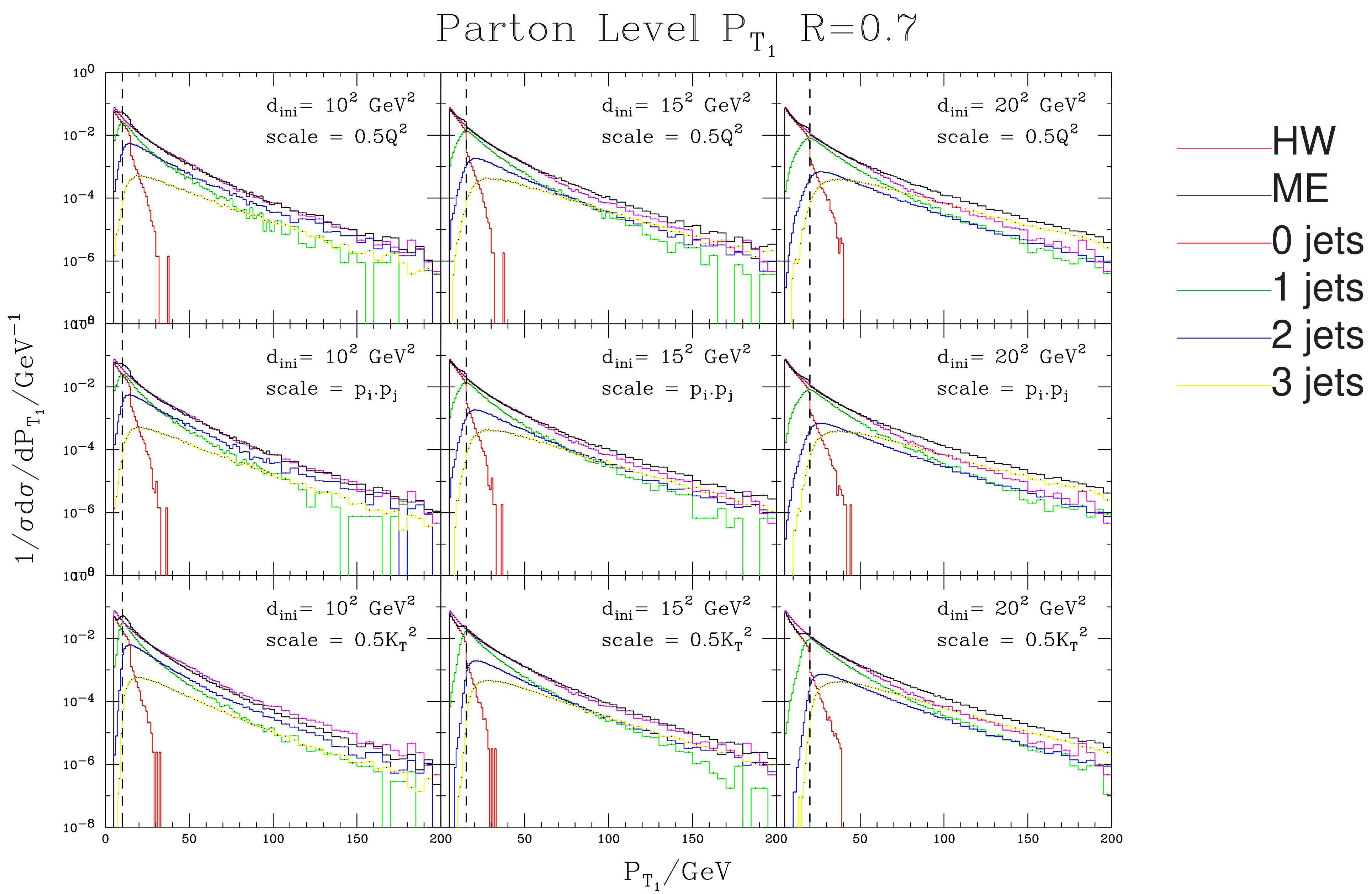
d_{ini}= 15^2 GeV^2
scale = $0.5Q^2$
d_{ini}= 20^2 GeV^2
scale = $0.5Q^2$
d_{ini}= 10^2 GeV^2
scale = $p_i.p_j$
d_{ini}= 15^2 GeV^2
scale = $p_i.p_j$
d_{ini}= 20^2 GeV^2
scale = $p_i.p_j$
d_{ini}= 10^2 GeV^2
scale = $0.5K_T{}^2$
d_{ini}= 15^2 GeV^2
scale = $0.5K_T{}^2$
d_{ini}= 20^2 GeV^2
scale = $0.5K_T{}^2$
HW
ME
0 jets
1 jets
2 jets
3 jets
$1/\sigma d\sigma/dP_{T_2}/GeV^{-1}$
P_{T_2}/GeV



Parton Level P_{T_1} R=0.7
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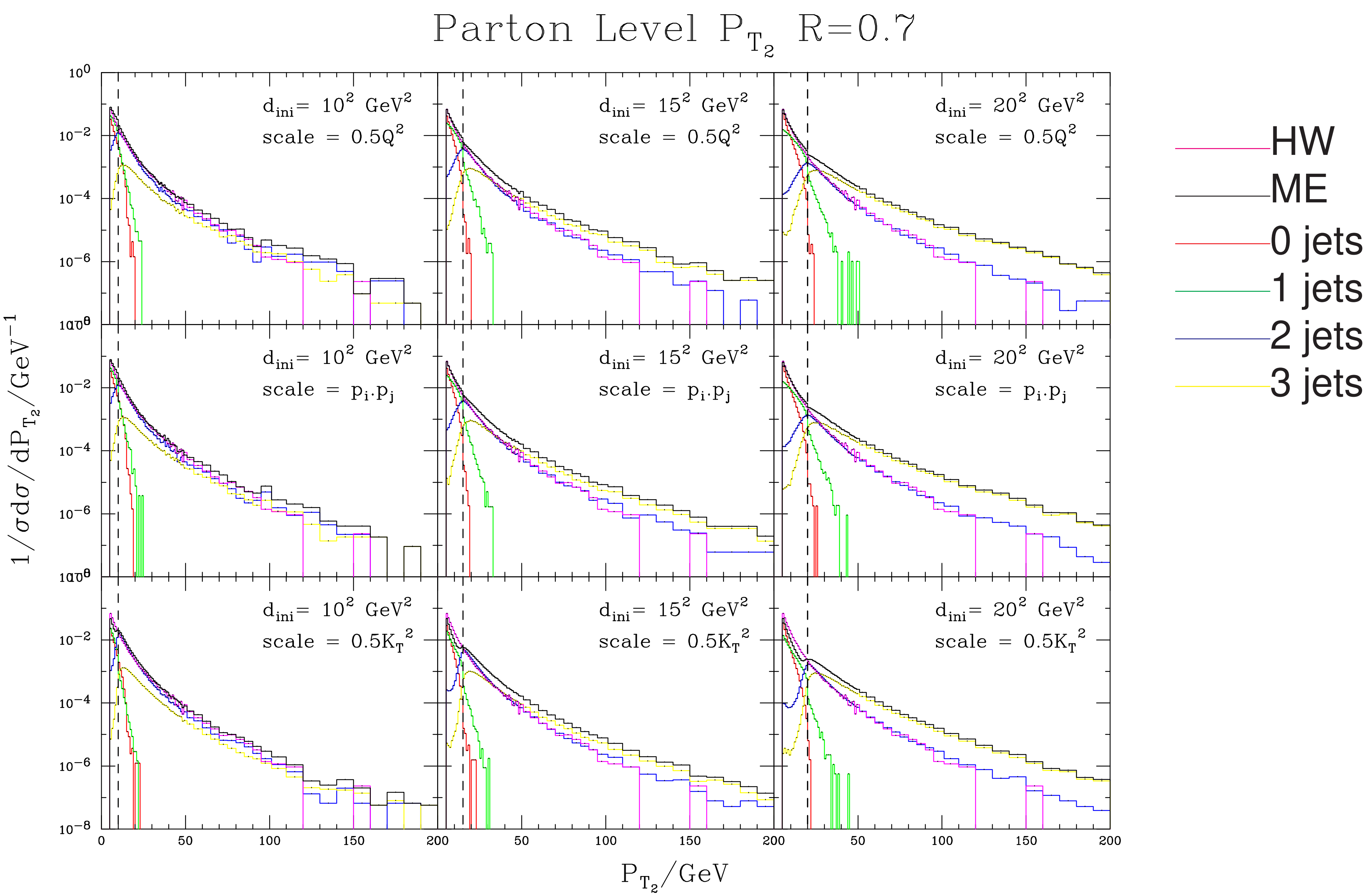
$d_{ini}= 15^2$ GeV^2
scale = $0.5Q^2$
$d_{ini}= 20^2$ GeV^2
scale = $0.5Q^2$
$d_{ini}= 10^2$ GeV^2
scale = $p_i.p_j$
$d_{ini}= 15^2$ GeV^2
scale = $p_i.p_j$
$d_{ini}= 20^2$ GeV^2
scale = $p_i.p_j$
$d_{ini}= 10^2$ GeV^2
scale = $0.5K_T{}^2$
$d_{ini}= 15^2$ GeV^2
scale = $0.5K_T{}^2$
$d_{ini}= 20^2$ GeV^2
scale = $0.5K_T{}^2$
$1/\sigma d\sigma/dP_{T_1}/\mathrm{GeV}^{-1}$
P_{T_1}/GeV
HW
ME
0 jets
1 jets
2 jets
3 jets



Parton Level P_{T_2} R=0.7
$d_{ini} = 10^2\ GeV^2$
scale = $0.5Q^2$
$d_{ini} = 15^2\ GeV^2$
scale = $0.5Q^2$
$d_{ini} = 20^2\ GeV^2$
scale = $0.5Q^2$
scale = $p_i.p_j$
scale = $0.5K_T{}^2$
$1/\sigma d\sigma/dP_{T_2}/GeV^{-1}$
P_{T_2}/GeV
HW
ME
0 jets
1 jets
2 jets
3 jets