Cross section and J/ψ production in Pythia8 for ep collision

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pythia8245 setup

SoftQCD	Pythia8	Pythia6
non-diffractive	101	95 (low-pt scattering)
A B -> A B elastic	102	91
A B -> X B single diffractive	103	92
A B -> A X single diffractive	104	93
A B -> X X double diffractive	105	94

```
pythia.readString("Beams:frameType = 2");
pythia.readString("Beams:idA = 11");
pythia.readString("Beams:idB = 2212");
pythia.readString("Beams:eA = 18.");
pythia.readString("Beams:eB = 275.”);

pythia.readString("PDF:lepton2gamma = on");
pythia.readString("PDF:lepton2gammaSet = 1”);

pythia.readString("SoftQCD:all= on”);//Common switch for the group of all soft QCD processes
pythia.settings.parm("PhaseSpace:Q2Min", 0);
pythia.settings.parm(“Photon:Q2max”,100);
pythia.readString("Photon:Wmin = 2”);

pythia.readString("SpaceShower:dipoleRecoil = on”);
pythia.settings.forceParm(“PhaseSpace:pTHatMinDiverge",0.5);
pythia.readString("SpaceShower:pTmaxMatch = 2”);
pythia.readString(“PhaseSpace:pTHatMin=1.624”);//The minimum invariant pT, same value as Pythia6
//p⊥min(s) = (1.9GeV)(s/1Tev2)^0.08
pythia.readString("SigmaElastic:Coulomb=on");
pythia.readString("PartonLevel:MPI = on”);
pythia.readString("PartonLevel:all= on");
pythia.readString("MultipartonInteractions:pTmin = 1.9”);//Lower cutoff in pT, below which no further
interactions are allowed
```

pythia8245 setup

SoftQCD

- non-diffractive
- A B -> A B elastic
- A B -> X B single diffractive
- A B -> A X single diffractive
- A B -> X X double diffractive

In Pythia6, in ‘resolved’ VMD or GVMD, for the resolved photons, perturbation theory does not provide a unique answer, so the cross sections are suppressed by dipole factors, $(m^2/(m^2 + Q^2))^2$, where m is the mass of the vector meson for a VMD state. So I add the same factor in Pythia8, it gives us a better agreement with Pythia6.

Suppression ratio:

non-diffractive: 93.48%

A B -> A B elastic: 93.63%

A B -> X B single diffractive :93.04%

A B -> A X single diffractive: 92.63%

A B -> X X double diffractive: 93.10%

pythia8245 setup

```
pythia.readString("Beams:frameType = 2");
pythia.readString("Beams:idA = 11");
pythia.readString("Beams:idB = 2212");
pythia.readString("Beams:eA = 18.");
pythia.readString("Beams:eB = 275.");

pythia.readString("PDF:lepton2gamma = on");
pythia.readString("PDF:lepton2gammaSet = 1”);

pythia.readString("HardQCD:all= on”);
//Common switch for the group of all hard QCD processes

pythia.settings.parm("PhaseSpace:Q2Min", 0);
pythia.settings.parm(“Photon:Q2max”,100);
pythia.readString("Photon:Wmin = 2”);

pythia.readString("SpaceShower:dipoleRecoil = on”);
pythia.settings.forceParm(“PhaseSpace:pTHatMinDiverge",0.5);
pythia.readString("SpaceShower:pTmaxMatch = 2”);
pythia.readString(“PhaseSpace:pTHatMin=1.624”);
//The minimum invariant pT, same value as Pythia6
pythia.readString("SigmaElastic:Coulomb=on");
pythia.readString("PartonLevel:MPI = on”);
pythia.readString("PartonLevel:all= on");
pythia.readString("MultipartonInteractions:pTmin = 1.9”);
//Lower cutoff in pT, below which no further interactions are allowed
```

hardQCD	PYTHIA8	PYTHIA6
f + f' -> f + f' (QCD)	114	11
f + fbar -> f' + fbar'	116,122	12
f + fbar -> g + g	115	13
f + g -> f + g	113	28
g + g -> f + fbar	112	53
g + g -> g + g	111	68

Photon-parton processes.

pythia8245 setup

```
pythia.readString("Beams:frameType = 2");
pythia.readString("Beams:idA = 11");
pythia.readString("Beams:idB = 2212");
pythia.readString("Beams:eA = 18.");
pythia.readString("Beams:eB = 275.");

pythia.readString("PDF:lepton2gamma = on");
pythia.readString("PDF:lepton2gammaSet = 1”);

pythia.readString("PhotonParton:all= on");//Common switch for Photon-parton production
processespythia.settings.parm("PhaseSpace:Q2Min", 0);
pythia.settings.parm(“Photon:Q2max”,100);
pythia.readString("Photon:Wmin = 2”);
```

Direct Process	PYTHIA8	PYTHIA6
f + gamma*_T -> f + g	284	131
f + gamma*_L -> f + g		132
g + gamma*_T -> f + fbar	282	135
g + gamma*_L -> f + fbar		136
gamma + q -> q + gamma	285	

```
pythia.readString("SpaceShower:dipoleRecoil = on”);
pythia.settings.forceParm(“PhaseSpace:pTHatMinDiverge",0.5);
pythia.readString("SpaceShower:pTmaxMatch = 2”);
pythia.readString(“PhaseSpace:pTHatMin=1.624”);//The minimum invariant pT, same value as Pythia6
pythia.readString("SigmaElastic:Coulomb=on");
pythia.readString("PartonLevel:MPI = on”);
pythia.readString("PartonLevel:all= on");
pythia.readString("MultipartonInteractions:pTmin = 1.9”);//Lower cutoff in pT, below which no
further interactions are allowed
```

pythia8245 setup

LO DIS

LO DIS	Pythia 8	Pythia6
f f' -> f f'	211	99

```
pythia.readString("Beams:frameType = 2");
// BeamA = proton.
pythia.readString("Beams:idA = 2212");
pythia.settings.parm("Beams:eA", eProton);
// BeamB = electron.
pythia.readString("Beams:idB = 11”);
pythia.settings.parm("Beams:eB", eElectron);
// Set up DIS process within some phase space.
// Neutral current (with gamma/Z interference).
pythia.readString("WeakBosonExchange:ff2ff(t:gmZ) = on");
pythia.readString(“PhaseSpace:mHatMin=2");
pythia.settings.parm("PhaseSpace:Q2Min", 1);
pythia.readString(“PhaseSpace:pTHatMax=1.62”); //set pTHatMax to avoid the double-counting issue
with process 99
pythia.settings.forceParm(“PhaseSpace:pTHatMinDiverge”,0.5);
pythia.readString("MultipartonInteractions:pTmin = 1.9”);
// Set dipole recoil on. Necessary for DIS + shower.
pythia.readString("SpaceShower:dipoleRecoil = on");
pythia.readString("SpaceShower:pTmaxMatch = 2");

// QED radiation off lepton not handled yet by the new procedure.
pythia.readString("PDF:lepton = off");
pythia.readString("TimeShower:QEDshowerByL = off");
```

In Pythia6, the cross section of LO DIS (q + gamma* -> q) is modified by a factor $Q^2/(Q^2 + m^2_\rho)$ to provide a finite cross section in the $Q^2 \rightarrow 0$ limit. It seems that in Pythia8 there is no such treatment. The cross section in Pythia8 is divergent even I add the same factor in Pythia8. So for now we can only trust the $Q^2>1$ part in Pythia8. For $Q^2>1$, the cross section in Pythia8 with the same modified factor is 4.126E-04mb. It is consistent with Pythia6 (4.231E-04mb).

Process	PYTHIA6 (mb)	PYTHIA8+DIRE (mb)
f + f' -> f + f' (QCD)	1.361E-03	3.723E-04
f + fbar -> f' + fbar'	2.608E-05	5.175E-06
f + fbar -> g + g	3.585E-05	8.604E-06
f + g -> f + g	4.332E-03	1.693E-03
g + g -> f + fbar	5.650E-05	3.439E-05
g + g -> g + g	2.423E-03	1.486E-03
Elastic scattering	3.733E-03	3.751E-03
Single diffractive (XB)	2.269E-03	2.087E-03
Single diffractive (AX)	1.904E-03	2.501E-03
Double diffractive	1.198E-03	1.343E-03
Low-pT scattering	1.306E-02	
Non-diffraction		2.667E-02
q + gamma* -> q (all Q^2)	2.274E-02	
q + gamma* -> q ($Q^2 > 1$)	4.231E-04	4.126E-04
f + gamma*_T -> f + g	4.207E-04	1.265E-04
f + gamma*_L -> f + g	1.850E-06	
g + gamma*_T -> f + fbar	1.120E-03	2.807E-04
g + gamma*_L -> f + fbar	1.944E-05	
gamma + q -> q + gamma		1.035E-06

softQCD process Pythia8
softQCD process Pythia6
Q^2 (GeV^2)

hardQCD process Pythia8
hardQCD process Pythia6
Q^2 (GeV^2)

direct process Pythia8
direct process Pythia6
Q^2 (GeV^2)

DIS process Pythia8
DIS process Pythia6
Q^2>1
Q^2 (GeV^2)

softQCD Pythia8
softQCD Pythia6
Q^2 (GeV^2)
x

hardQCD Pythia8
hardQCD Pythia6
Q^2 (GeV^2)
x

direct process Pythia8
direct process Pythia6
Q^2 (GeV^2)
x

LO DIS Pythia8
LO DIS Pythia6
$Q^2>1$
Q^2 (GeV^2)
x

W_softQCD

softQCD Pythia8

softQCD Pythia6

W (GeV)

hardQCD Pythia8

hardQCD Pythia6

W (GeV)

direct process Pythia8

direct process Pythia6

W (GeV)

LO DIS Pythia8

LO DIS Pythia6

$Q^2>1$

W (GeV)

softQCD Pythia8
softQCD Pythia6
hardQCD Pythia8
hardQCD Pythia6
direct process Pythia8
direct process Pythia6
LO DIS Pythia8
LO DIS Pythia6
$Q^2>1$
y

J/ψ production in Pythia8

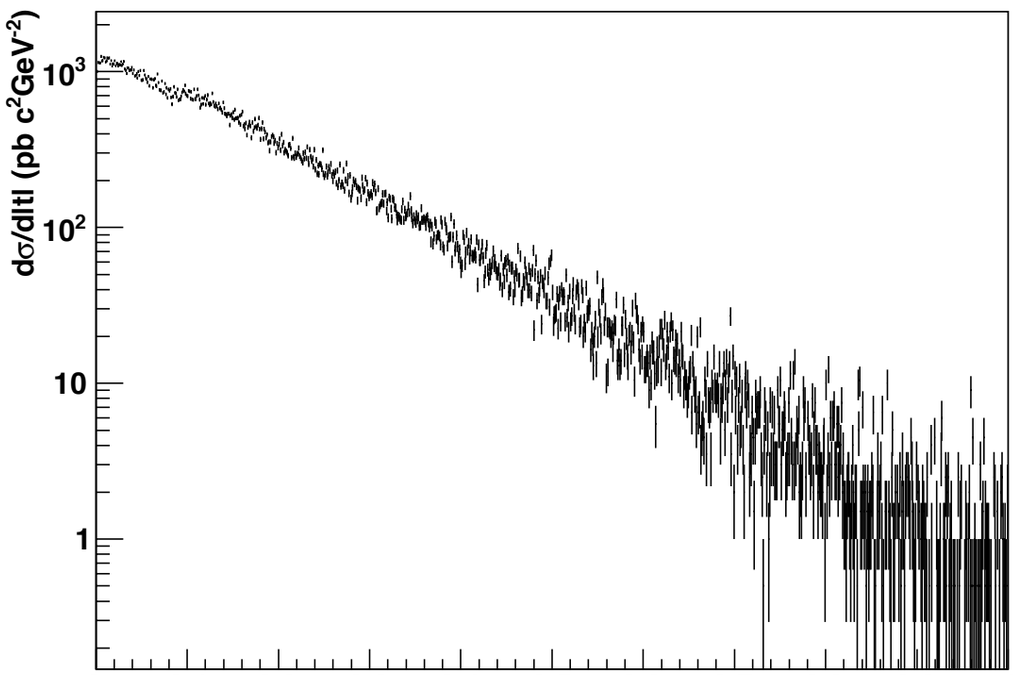
- Pythia8 actually doesn’t have the minimum true Q2 cut. This Q2 cut (PhaseSpace:Q2Min) is for the sub process, it is not the true Q2. To improve the efficiency, I modified the source code of Pythia8 to add a new cut for the true Q2, named as "Photon:Q2min”. It is quite safe as I only add a filter before the event simulation.

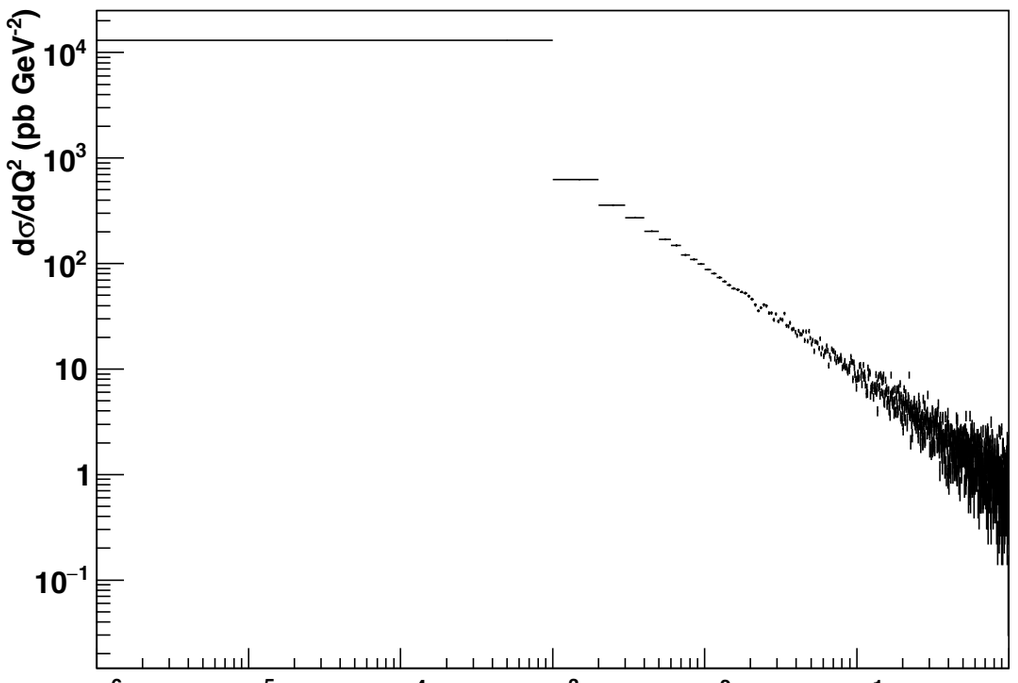
- Another modification I made is the cut named Photon:Q2max. It already exists in Pythia8, but the current framework can handle only (quasi-)real photons, a upper limit for the photon virtuality is set to maximum = 2.0 in the model. I slightly reset the maximum value to 10 to check the jpsi production between 1<Q2<10.

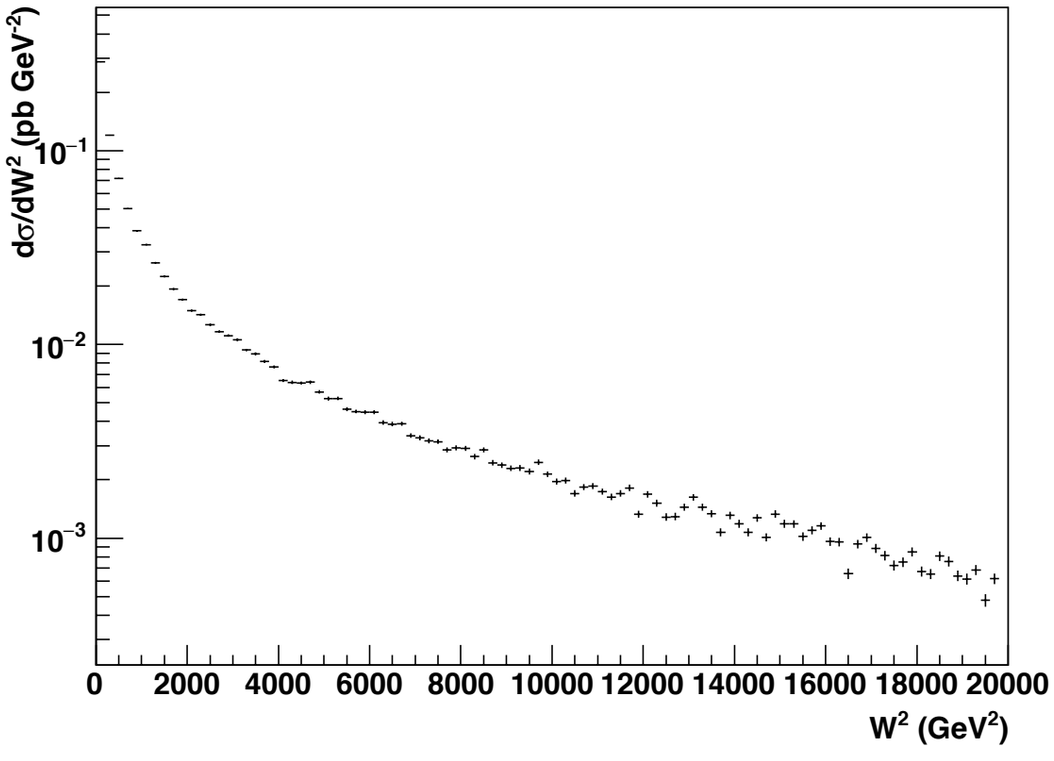
$e+p \rightarrow e + p + J/\psi$

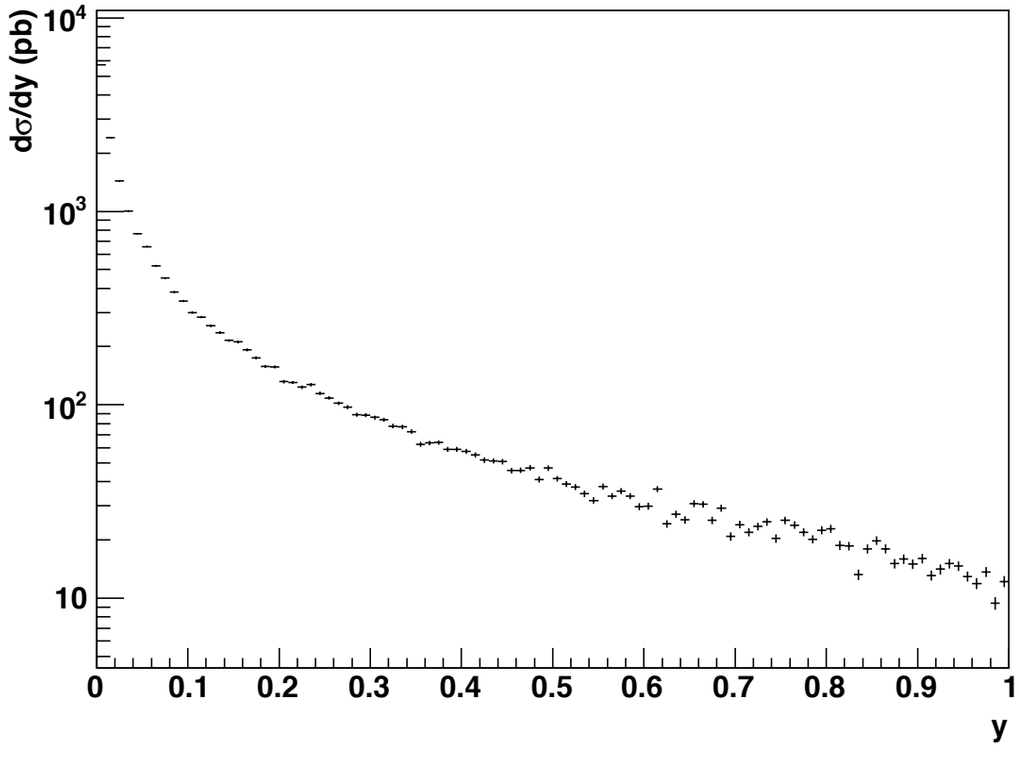
elastic process (A B -> A B elastic)

$Q^2 < 1\ GeV^2$
$x < 0.01$
$|\eta(e_{decay})| < 4$
$p(e_{decay}) > 1\ GeV/c$



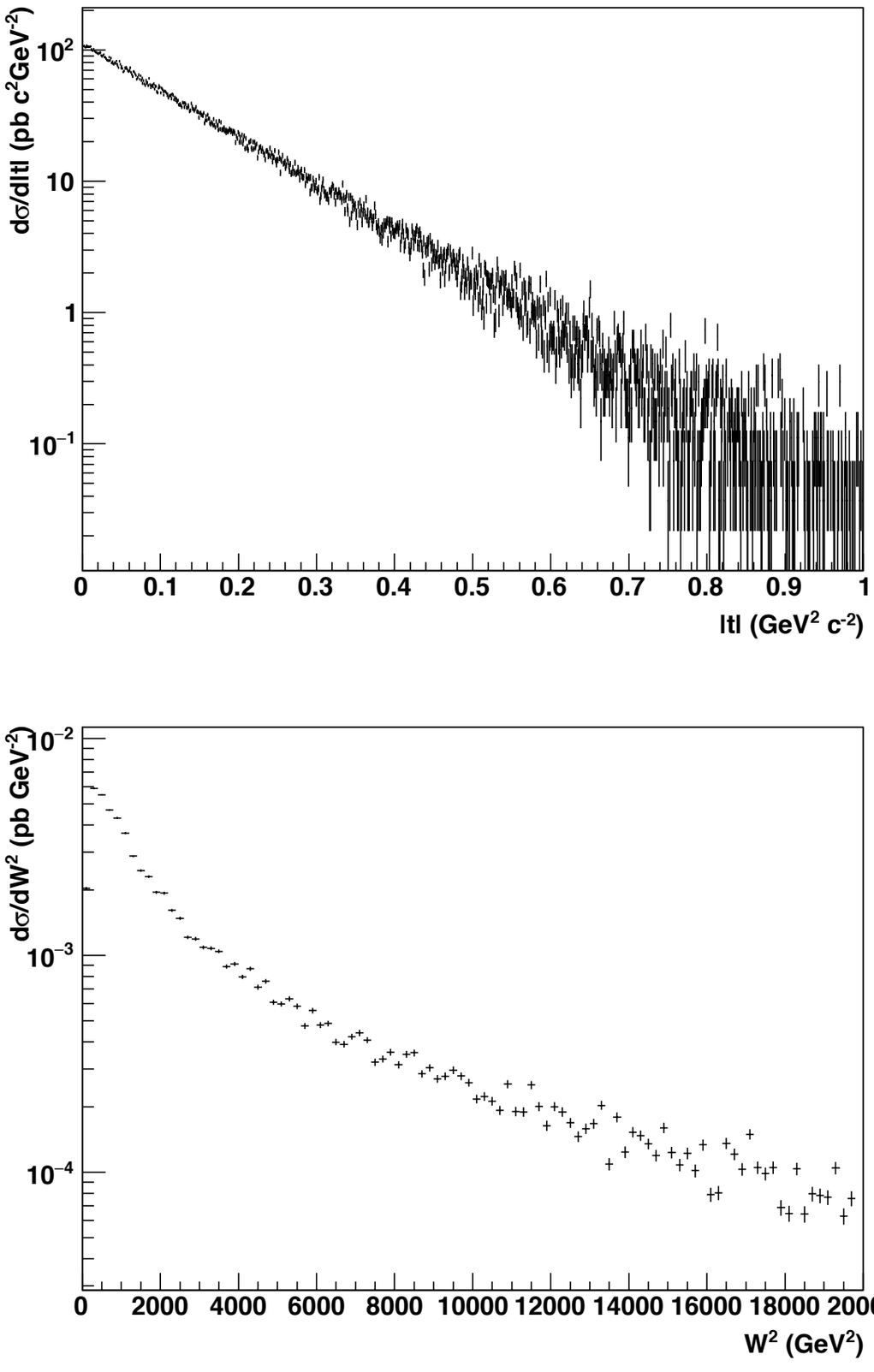


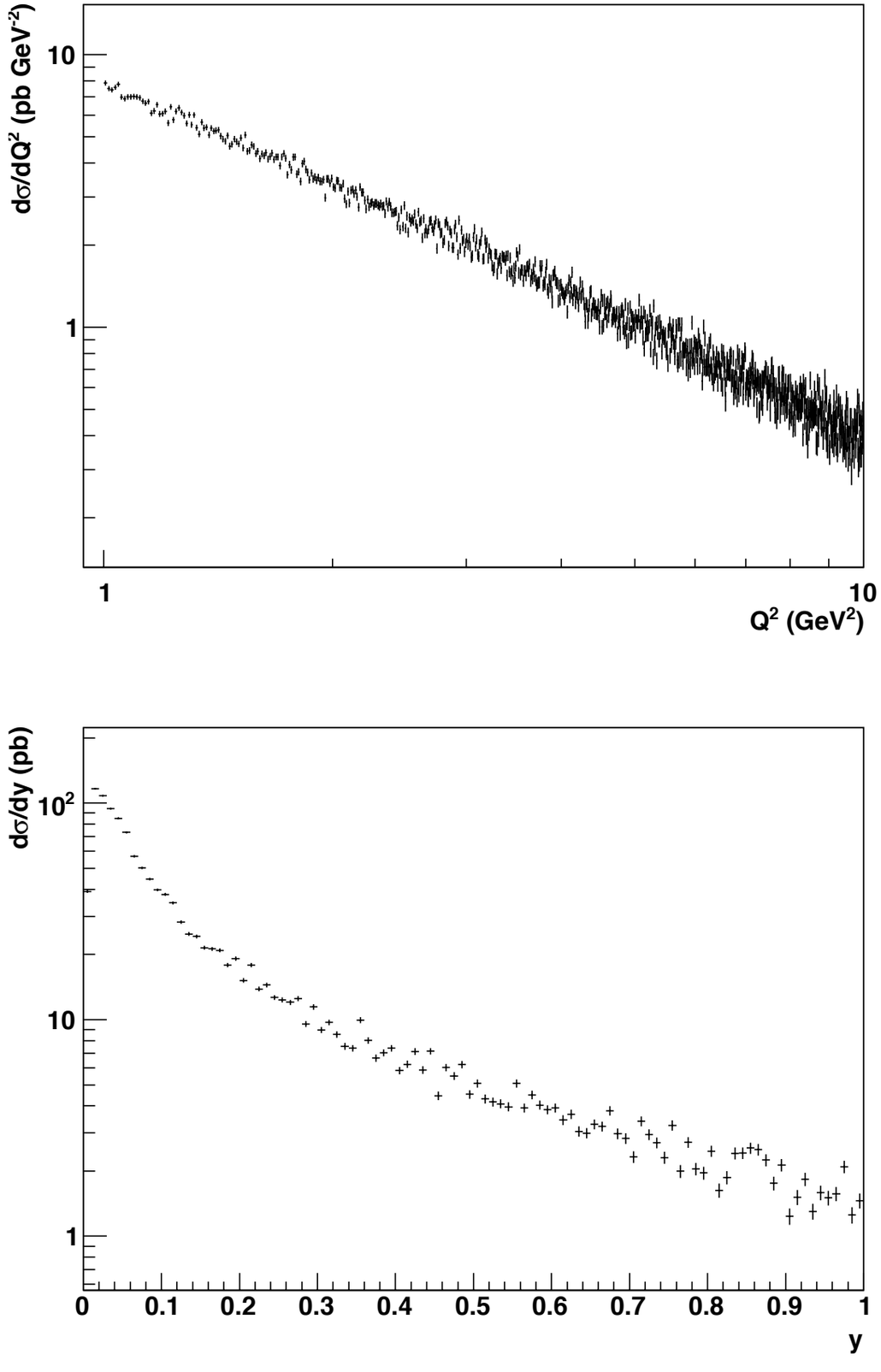




$e+p \rightarrow e + p + J/\psi$

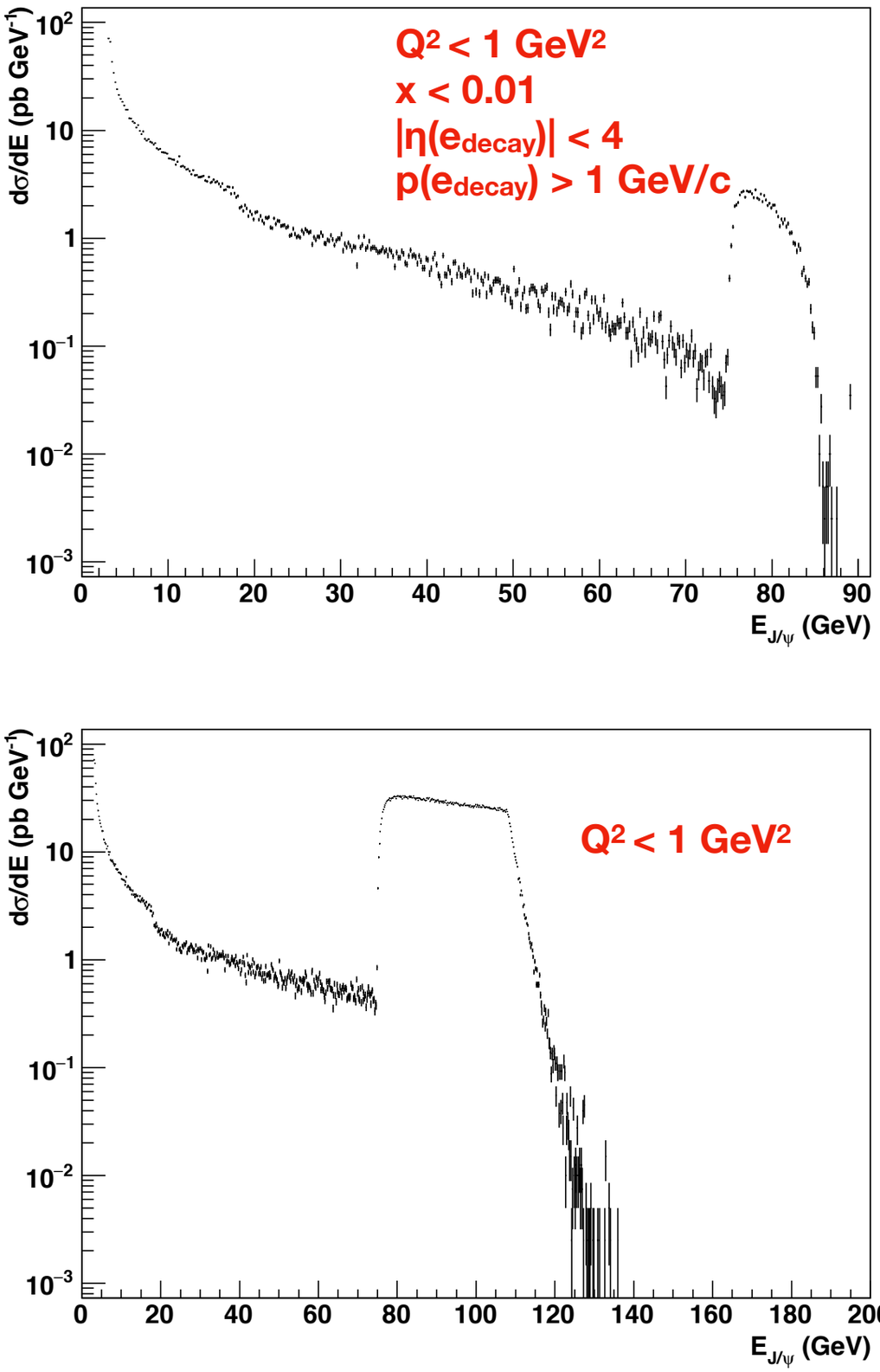
$1 < Q^2 < 10\ GeV^2$
$x < 0.01$
$|\eta(e_{decay})| < 4$
$p(e_{decay}) > 1\ GeV/c$

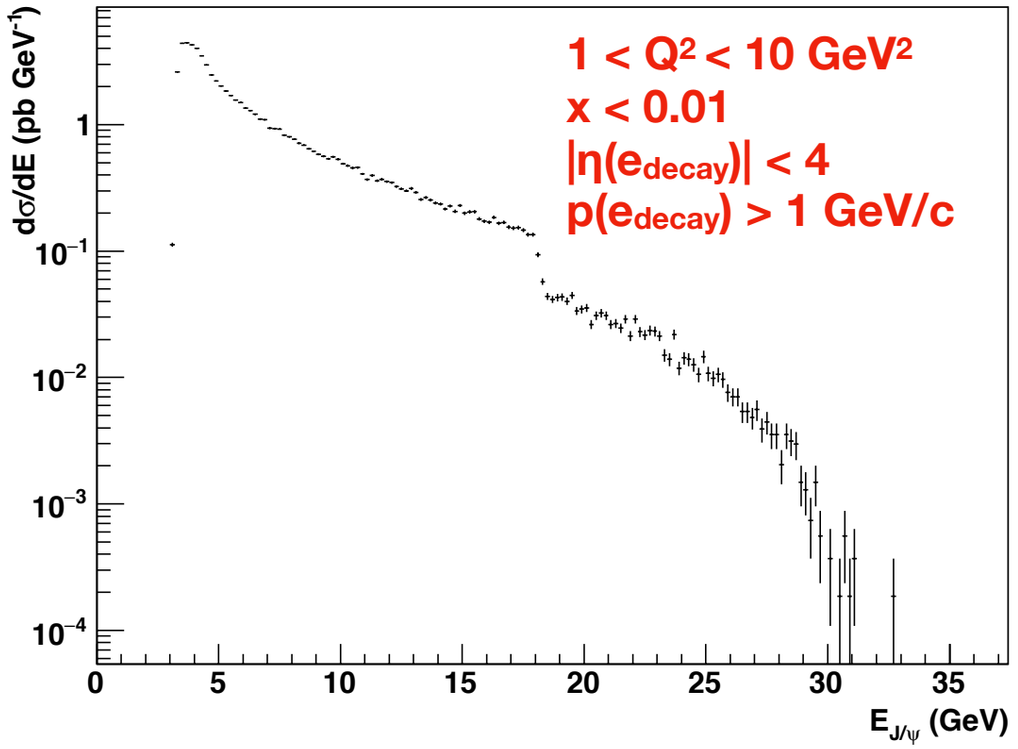


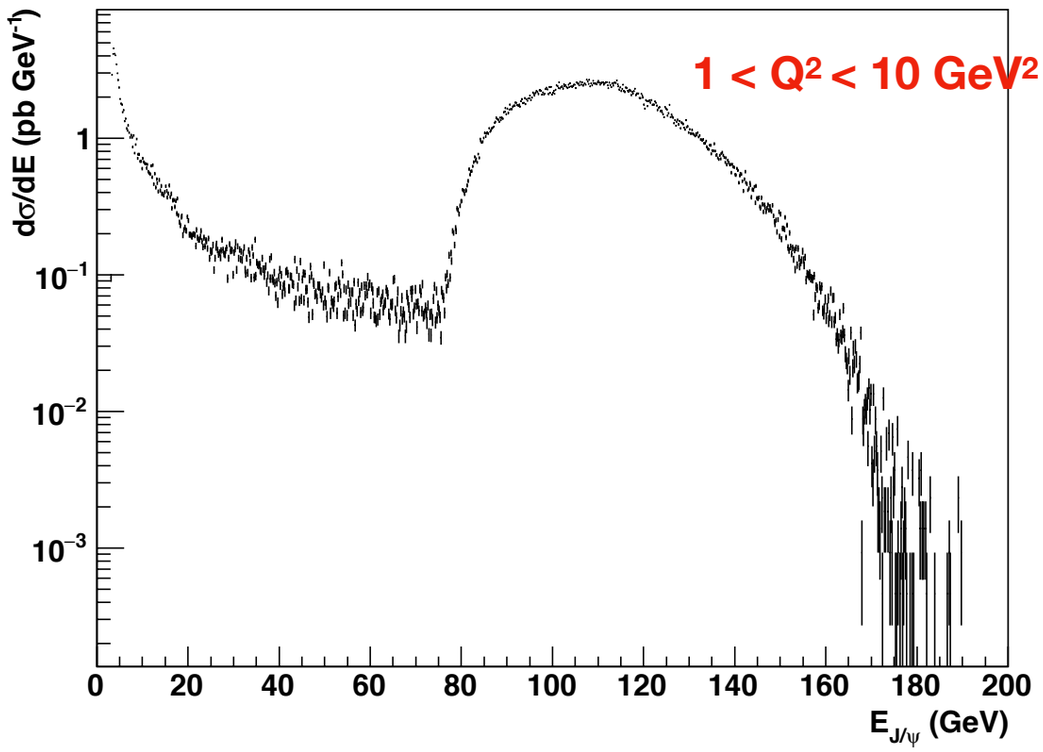


e+p → e + p + J/ψ

- In Pythia8, there is a lot of Jpsi with large energy which is not found in Pythia6. The large energy Jpsi are very forward, the eta cut for the decayed electrons can veto most of them especially for Q2>1.







Thanks!