Using γ + Jets production to calibrate $Z (\rightarrow \nu\nu)$ + Jets at the LHC

M Shea, WJ Stirling
T Sandoval, A Parker
Cambridge University, Cavendish Laboratory CB3 0HE

Motivation

- $Z (\rightarrow \nu\nu)$ + Jets is an important Standard Model background for SUSY searches at LHC

- In principle, it can be calibrated using $Z (\rightarrow ee, \mu\mu)$ + Jets, but the rates are small

- Instead, use γ + Jets production: much larger rates and clean signal

- We show that the γ,Z + Jets production rates are closely correlated, especially at high vector boson p_T

Outline

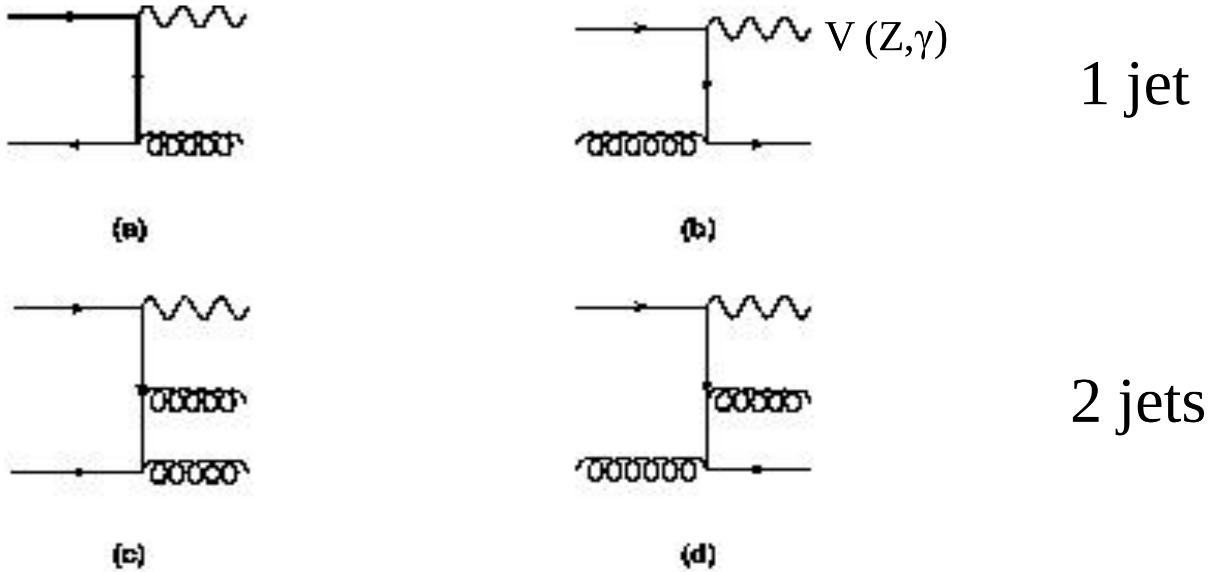
- M Shea and WJ Stirling (theory) investigate this calibration at 14 TeV using the parton-level MC Gambos, an adaptation of Vecbos [1]

- T Sandoval and A Parker (experimental) use the Pythia and Alpgen ATLAS Monte Carlo generators at 14 TeV

- We will explain our motivation behind the work and briefly summarise our results thus far, including any necessary differences in approach between the theory and experiment work.

Theory Motivation

The hard scattering γ,Z + Jets processes only differ because of the EW vertex factors and the Z mass (representative Feynman diagrams for Vector boson + Jets):



Therefore we expect that for $p_T \gg M_Z$ the Z/ γ ratio will be determined by the ratio of the respective couplings to quarks.

Coupling Constants

$$Z_q = \frac{\alpha_{em}(V_q^2 + A_q^2)}{4\,(\cos\theta_w \sin\theta_w)^2}$$

$$\gamma_q = \alpha_{em} e_q^2$$

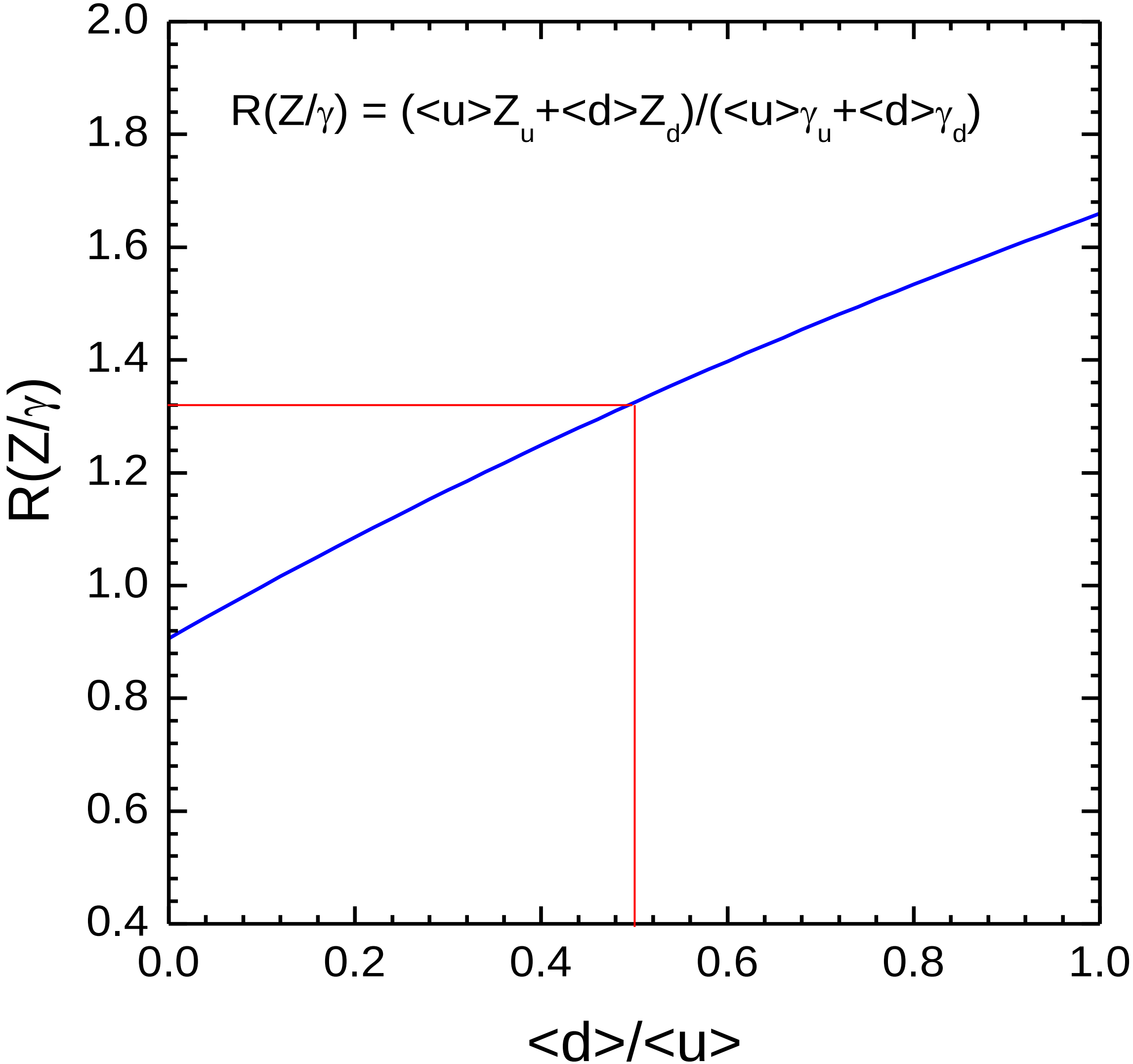
$$R(Z/\gamma)_u = 0.906$$

$$R(Z/\gamma)_d = 4.673$$

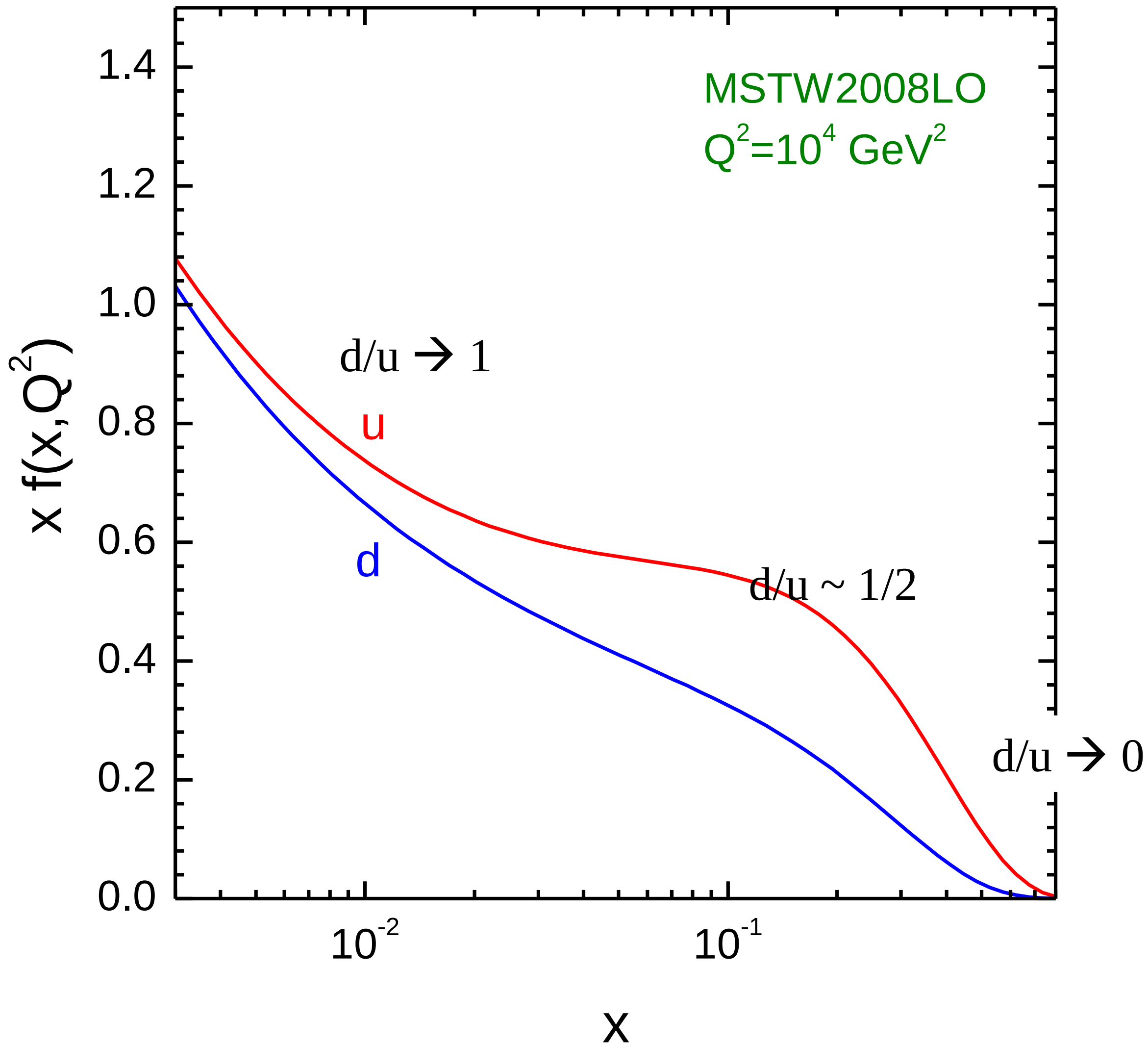
$$R(Z/\gamma) = \frac{(\langle u\rangle Z_u + \langle d\rangle Z_d)}{(\langle u\rangle \gamma_u + \langle d\rangle \gamma_d)}$$

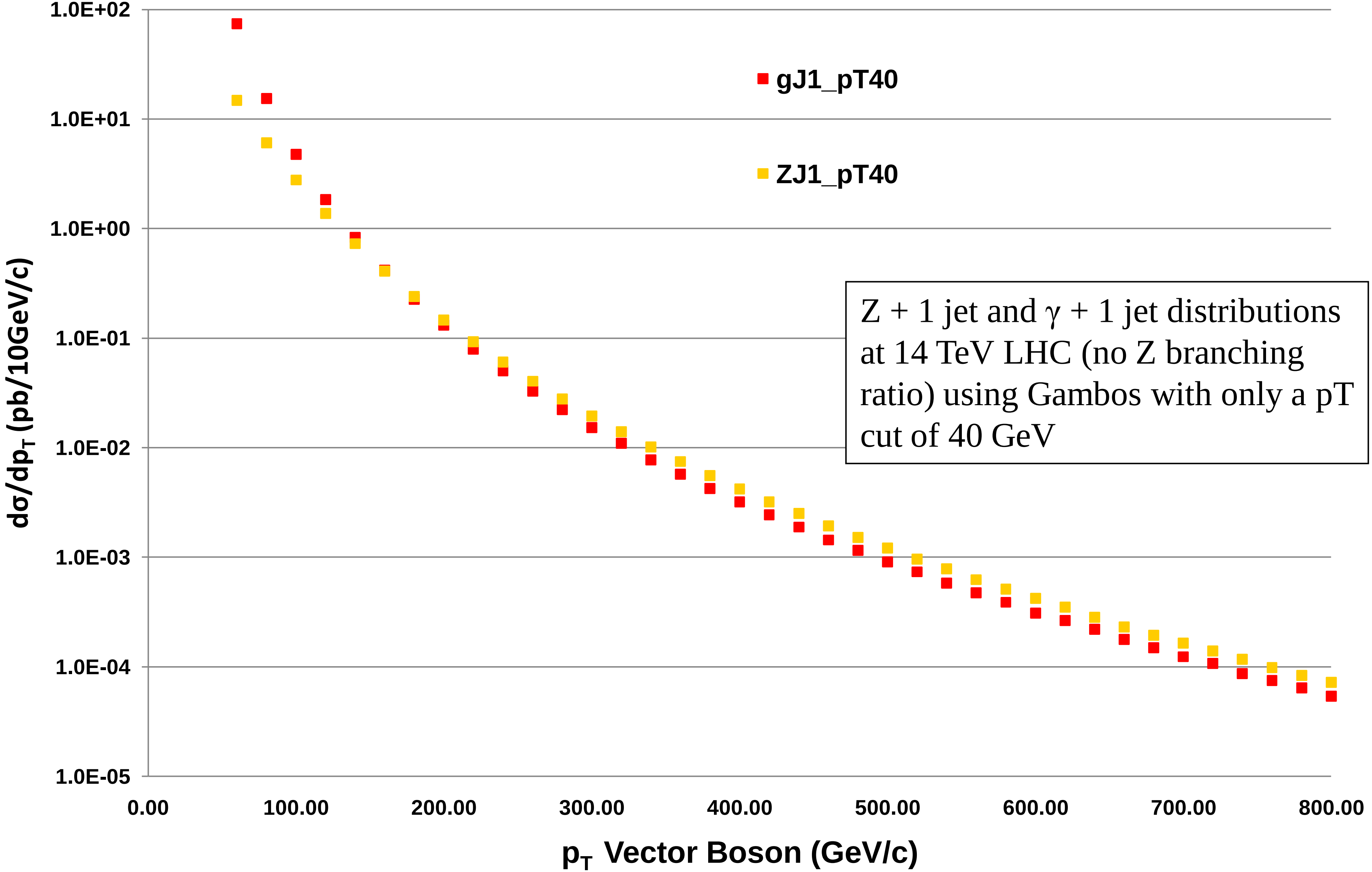
where <u> and <d> are typical values of the up and down distributions probed in the cross section calculation (and ignoring sea quarks)

First look at what to expect from Z/γ Ratio (determined by coupling constants)

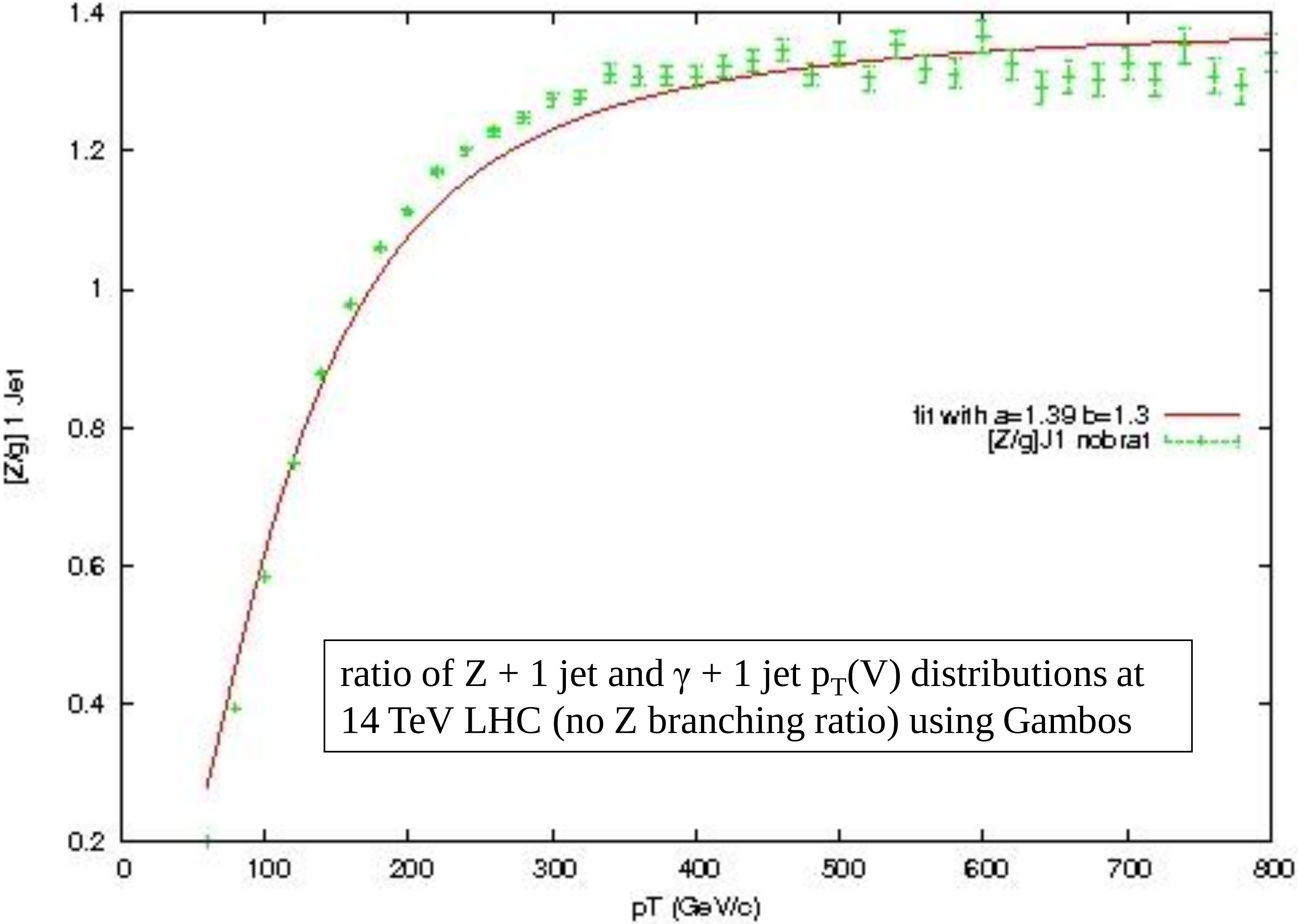


PDF Distributions





Z + 1 jet and γ + 1 jet distributions at 14 TeV LHC (no Z branching ratio) using Gambos with only a pT cut of 40 GeV



ratio of Z + 1 jet and γ + 1 jet $p_T(V)$ distributions at 14 TeV LHC (no Z branching ratio) using Gambos

Back of the Envelope Shape Explanation

$$Z \sim \left(\frac{1}{p_T^2 + M_Z^2}\right)^b \qquad \gamma \sim \left(\frac{1}{p_T^2}\right)^b$$

$$\frac{Z}{\gamma} \sim A\left(\frac{p_T^2}{p_T^2 + M_Z^2}\right)^b$$

fit gives: b = 1.3 and A = 1.39 – as anticipated from consideration of the Z, γ couplings (Slides 5, 6)

Run with Representative Cuts

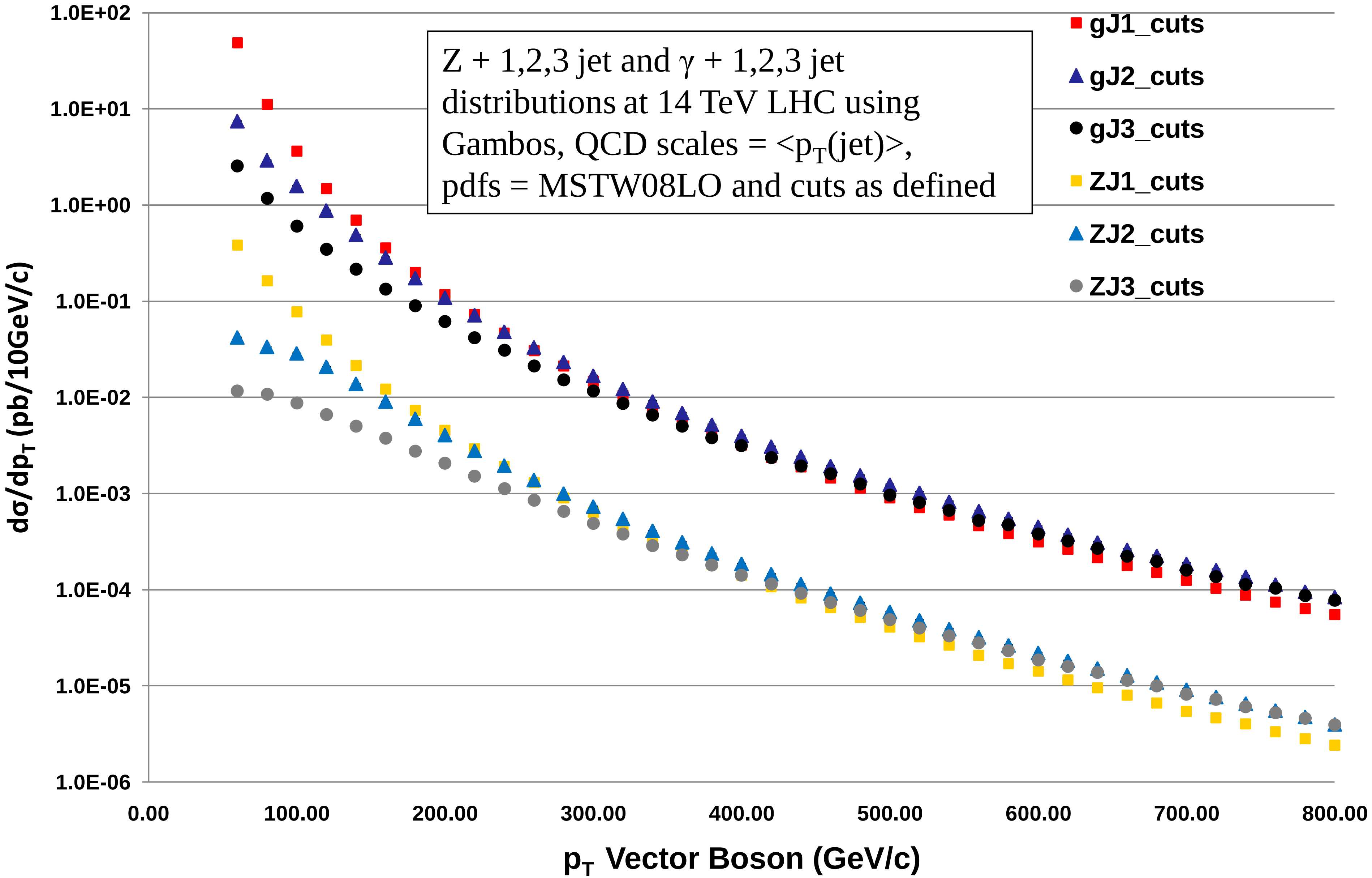
p_T cuts on vector boson and Jets: > 40 GeV

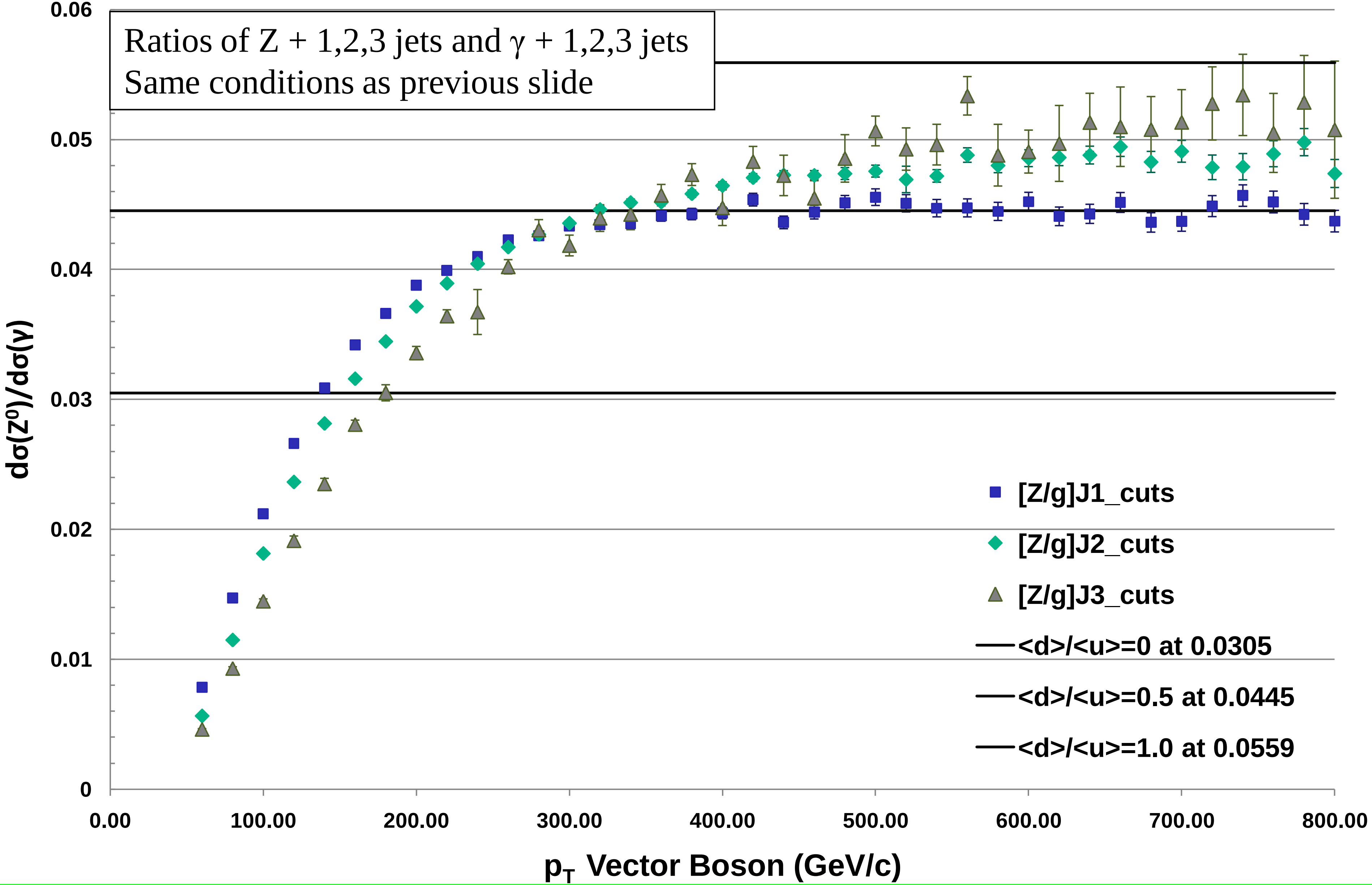
Rapidity cut on Jets: < 2.5

Separation cut on Jets: > 0.4

Separation cut on Jet-Boson: > 0.2

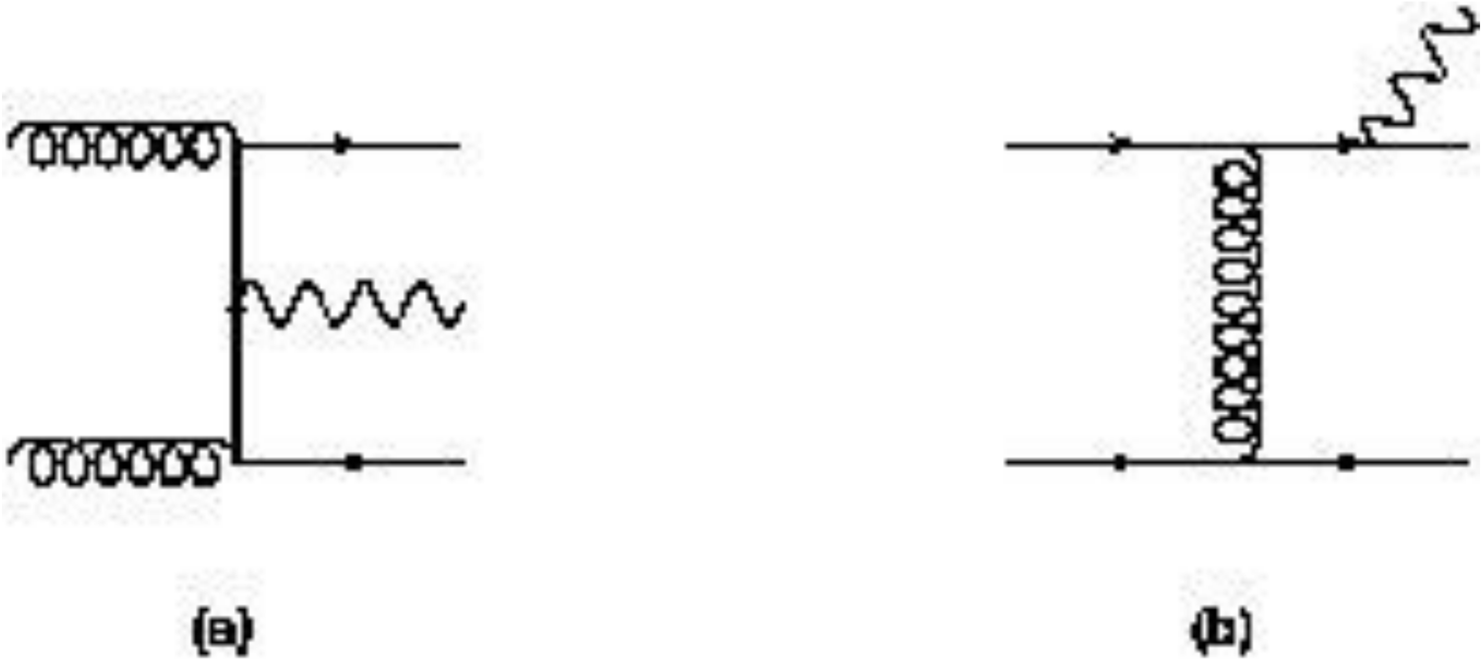
Z leptonic Branching Ratio = 0.033658


Z + 1,2,3 jet and γ + 1,2,3 jet distributions at 14 TeV LHC using Gambos, QCD scales = <pT(jet)>, pdfs = MSTW08LO and cuts as defined
gJ1_cuts
gJ2_cuts
gJ3_cuts
ZJ1_cuts
ZJ2_cuts
ZJ3_cuts
dσ/dpT (pb/10GeV/c)
pT Vector Boson (GeV/c)
1.0E+02
1.0E+01
1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00



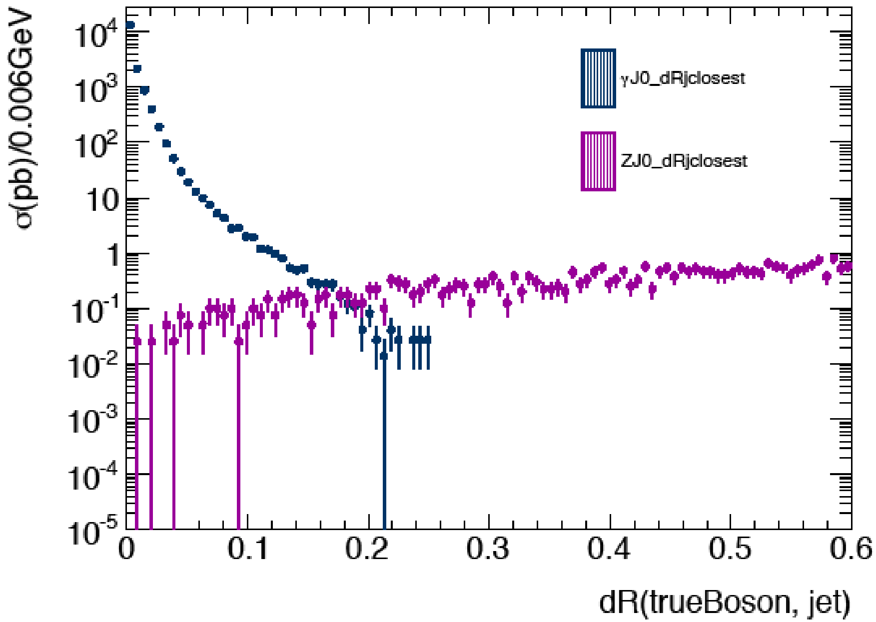
Ratios of Z + 1,2,3 jets and γ + 1,2,3 jets
Same conditions as previous slide
0.06
0.05
0.04
0.03
0.02
0.01
0
dσ(Z0)/dσ(γ)
0.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
800.00
pT Vector Boson (GeV/c)
[Z/g]J1_cuts
[Z/g]J2_cuts
[Z/g]J3_cuts
<d>/<u>=0 at 0.0305
<d>/<u>=0.5 at 0.0445
<d>/<u>=1.0 at 0.0559

Diagrams Available for >1 Jet

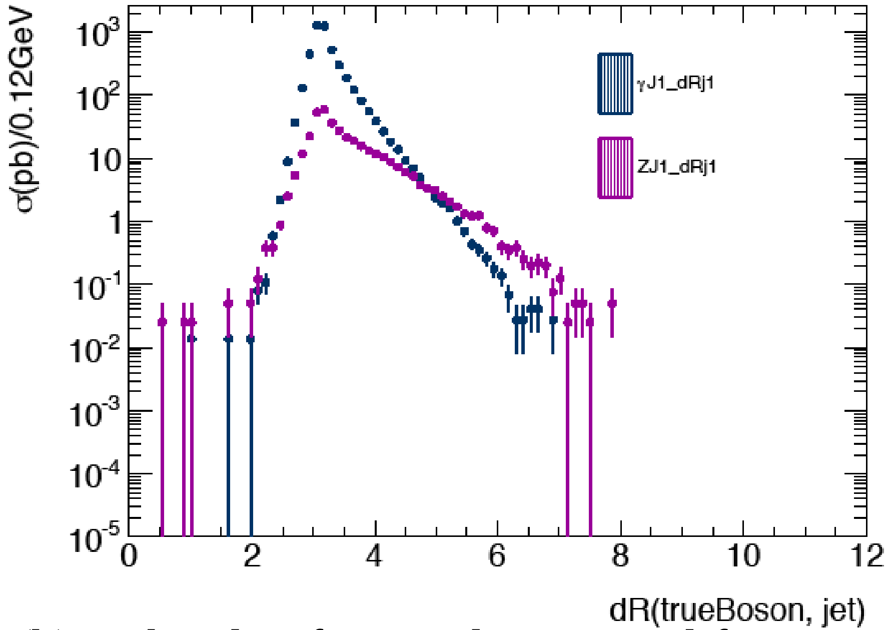


Both g-g and q-q processes cause the Z/γ + 2,3 jet ratios to stabilise at slightly higher values than for q-g and q-qbar processes alone

Boson-Jet Overlap Removal in Pythia and Alpgen



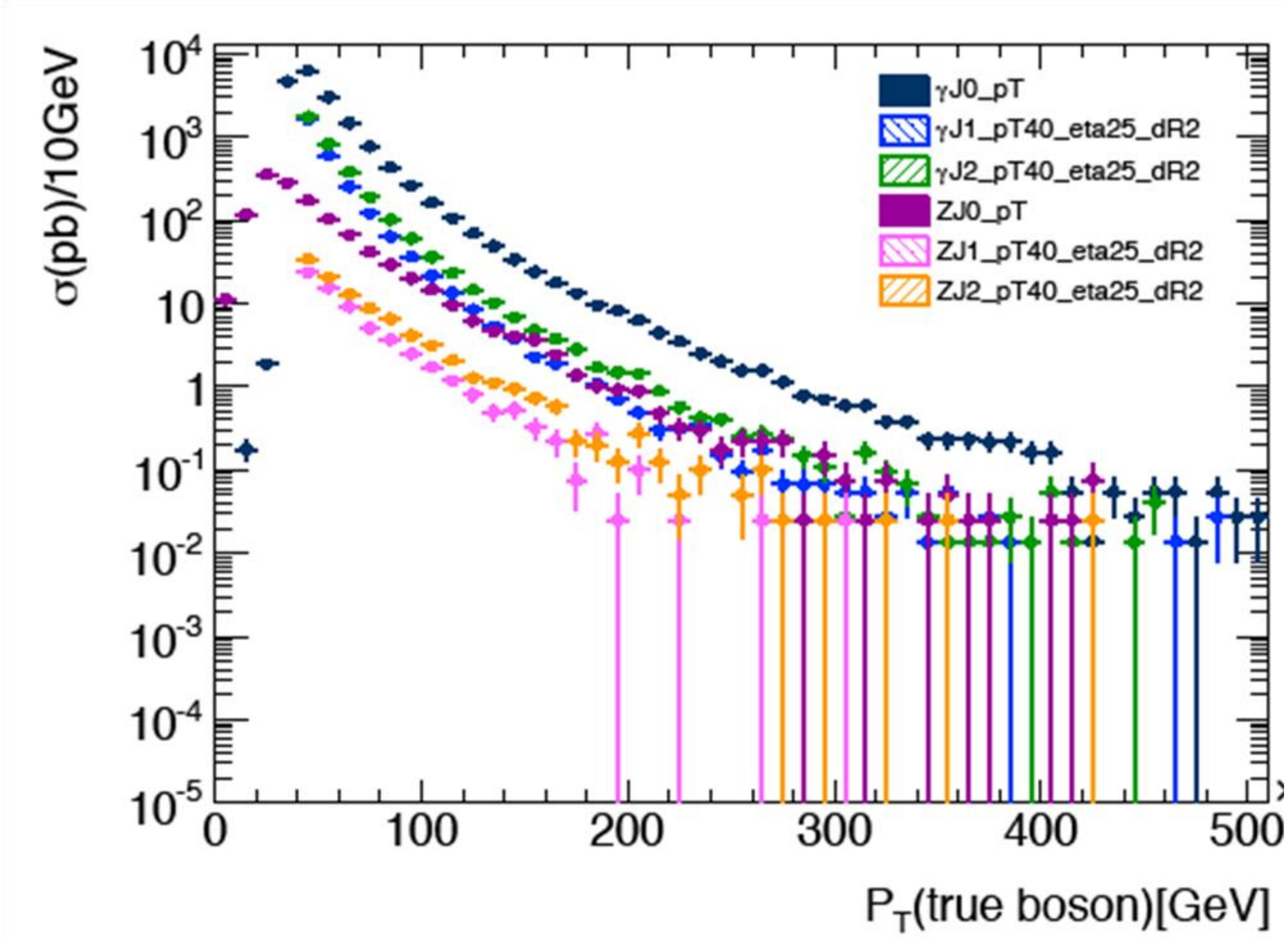
(a) Pythia dR before overlap removal of closest jet to boson



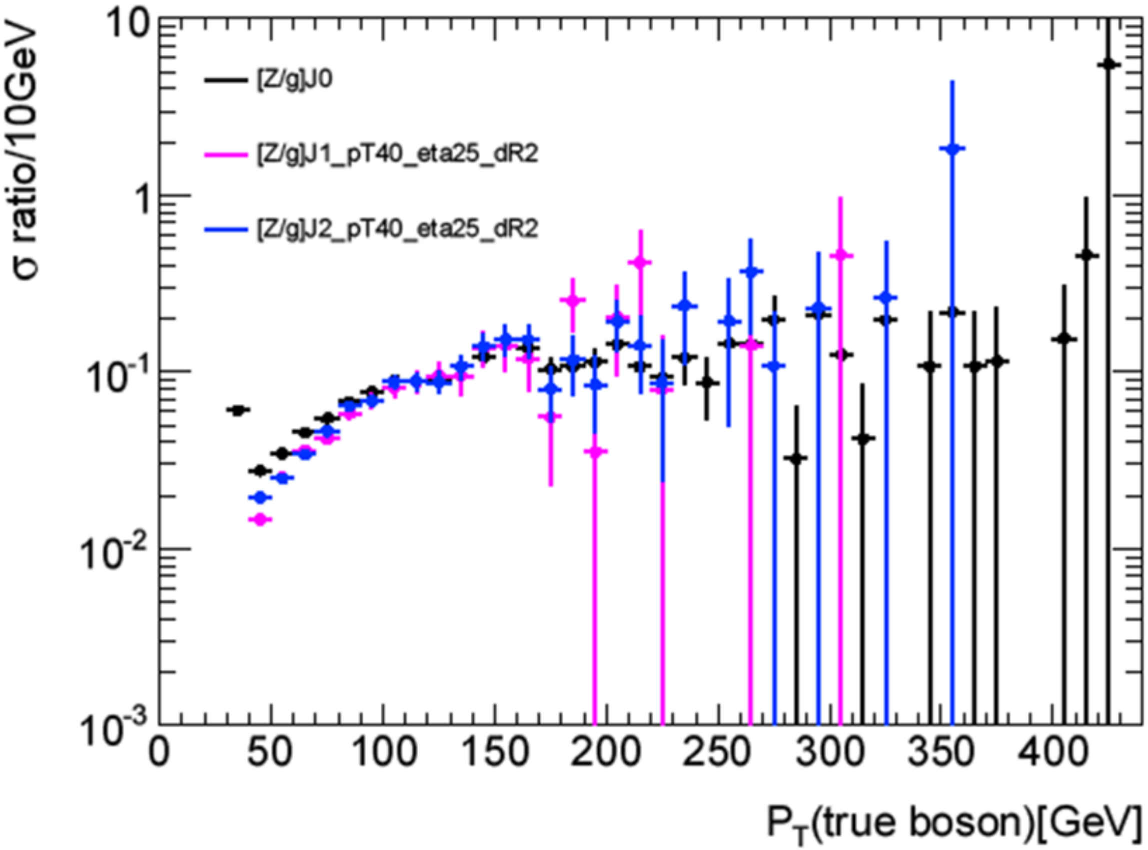
(b) Pythia dR after overlap removal for 1 Jet events

~99% of γ's had a jet with dR(γ, jet) < 0.2 . Z's did not suffer from this. Standard overlap removal method at reconstruction level is via a dR(boson, jet) < 0.2 cut

Differential cross-section as a function of boson p_T for processes pp → boson + jets using Pythia



Ratio of Z/γ using Pythia



Pythia plots were run with the $Z \rightarrow$ invisible branching ratio of 0.2000

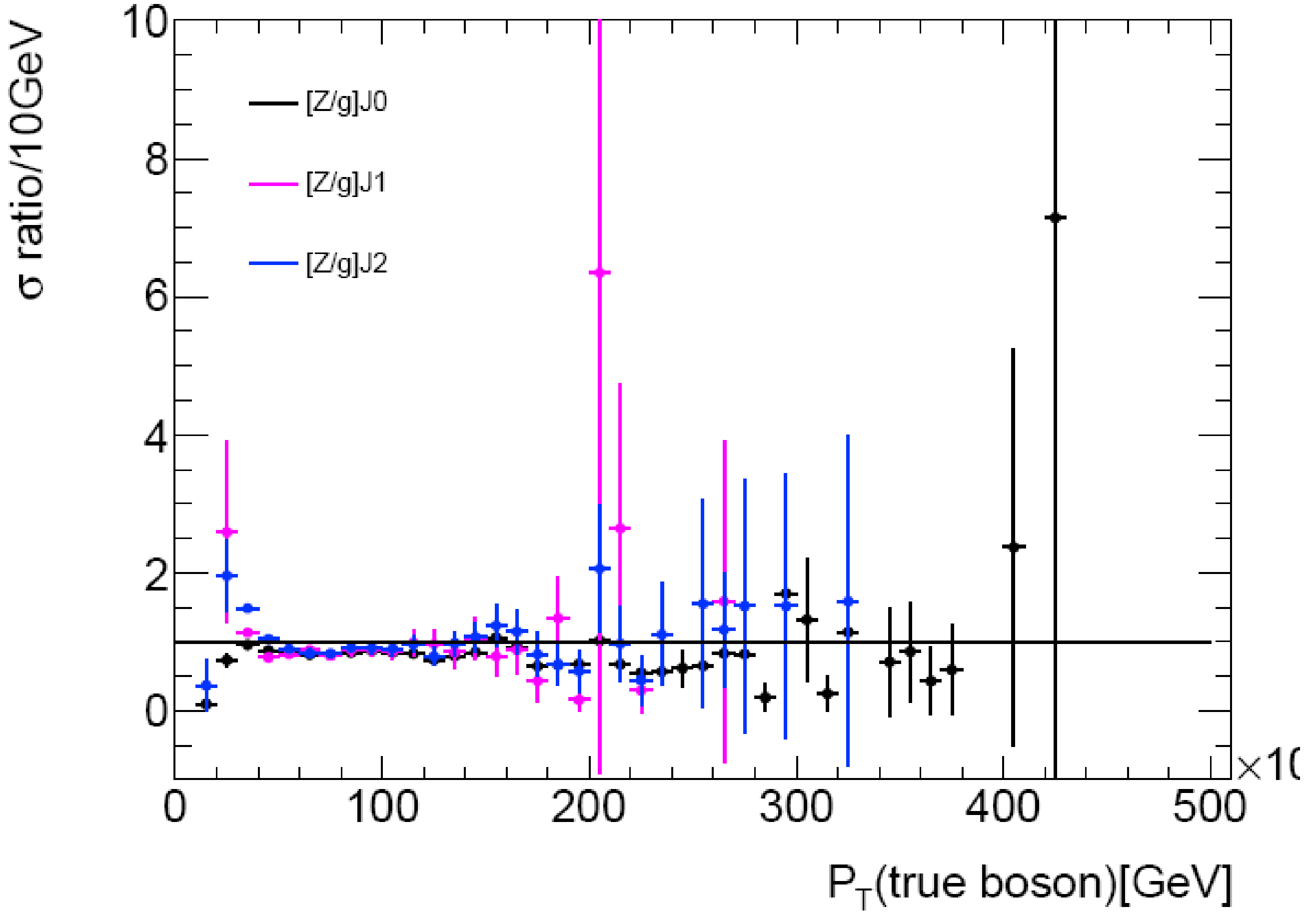
Conclusions

- At high $p_T(V)$, the Z/ γ + 1,2,3 jets ratios are roughly constant (~1.4, with no Z BR) and in line with theoretical expectations based on simple vertex coupling arguments and Z mass dependence
- They should therefore also be stable w.r.t. scale, pdf variations (work in progress!)
- Results obtained with Gambos (parton-level) and with Pythia/Alpgen are broadly in agreement
- The use of γ + n jets to calibrate Z ($\rightarrow\nu\nu$) + n jets at high E_T(miss) therefore looks promising!

References

- Walter Giele, Vecbos, Available at: http://vircol.fnal.gov/MCdownload/vecbos.html
- C. Amsler et al. (Particle Data Group), Physics letter b667, 1 (2008) and 2009 partial update for the 2010 edition.
- Atlas Metadata Interface, Website, 2010: http://ami.in2p3.fr/opencms/opencms/AMI/www/
- Ellis, RK, WJ Stirling, and BR Webber, QCD and Collider Physics. *Cambridge Monographs on Particle Physics, Nuclear Physics, and Cosmology*. eds. T Ericson, PV Landshoff. Cambridge Uniseity Press: 1996.

Pythia vs Alpgen



PDF Distributions