Jet Energy Profiles for Electroweak Bosons

arXiv:1505.xxxx

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Motivation

- Distinguish highly boosted Electroweak bosons from fat QCD jets
- Distinguish highly boosted Electroweak bosons from each other
- Find an approximate form to calculate the Jet Energy Profile quickly

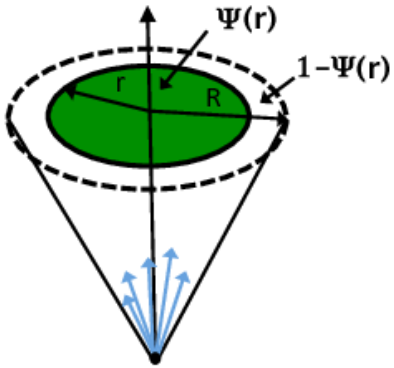


Figure : Image from arXiv:1204.3170

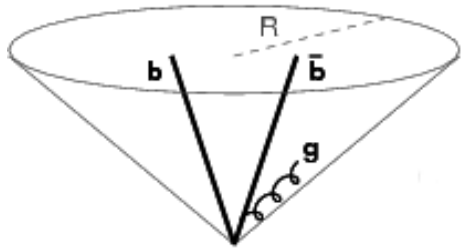


Figure : Image from arXiv:1106:2516

Definitions

Experimental Definition

$$\Psi(r) = \frac{1}{N_J} \sum_J \frac{\sum_{r_i<r} P_{T_i}}{\sum_{r_i<R} P_{T_i}}$$

With i over all the particles in the jet.

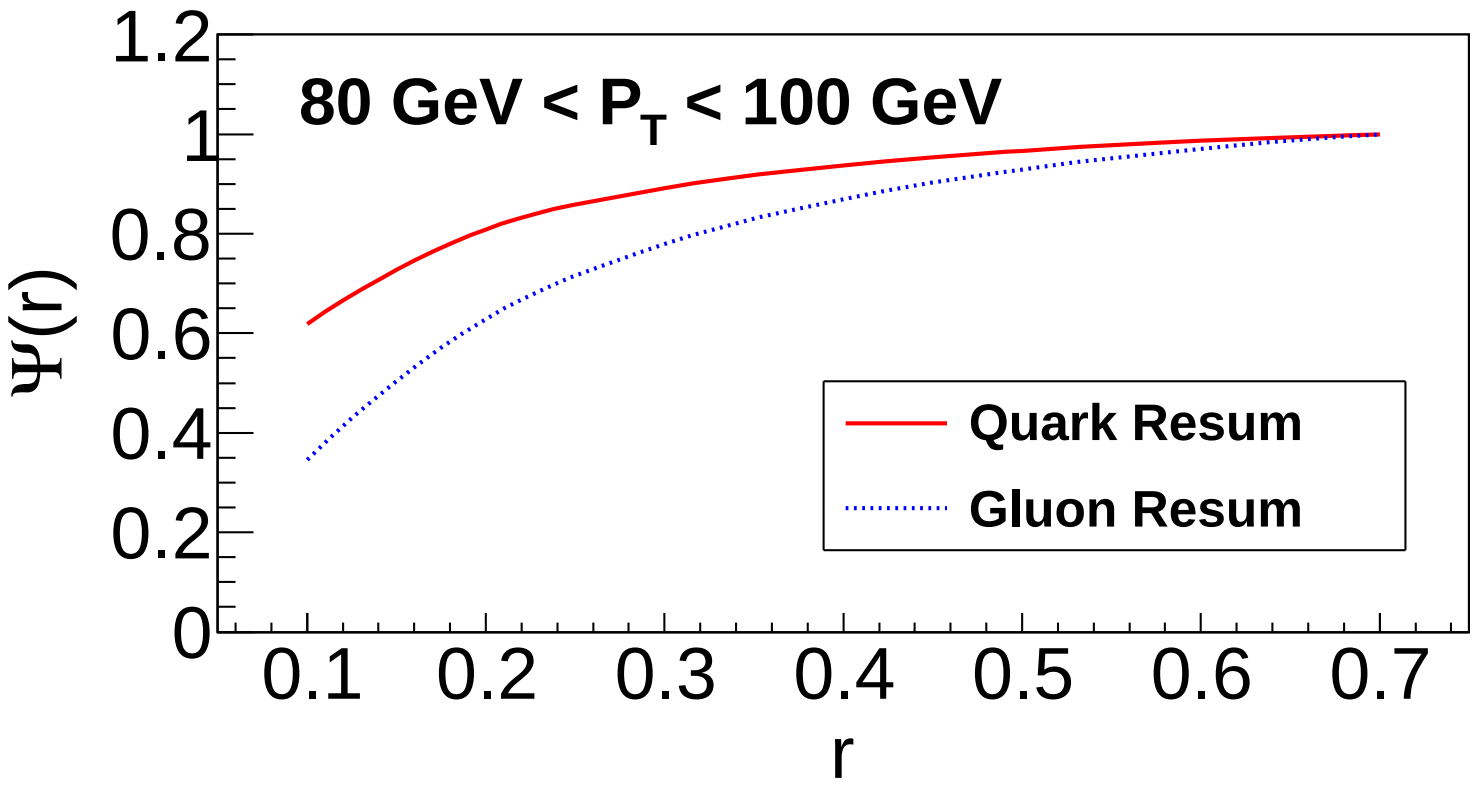
Theoretical Definition

$$\Psi(r) = \frac{\bar{J}^E(1, E_J, R, r)}{\bar{J}^E(1, E_J, R, R)}$$

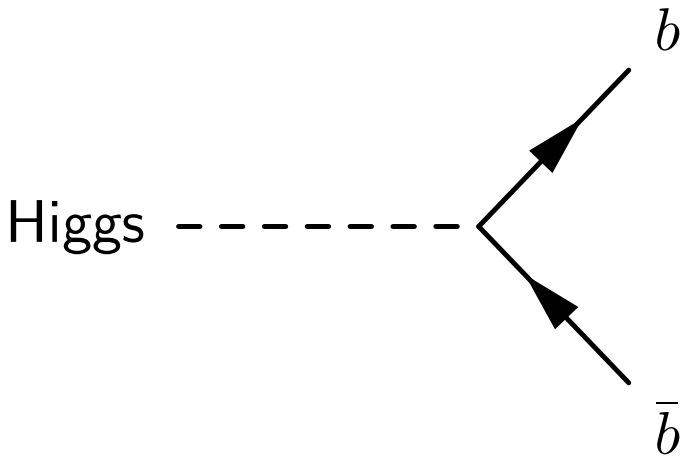
Where $\bar{J}^E(1, E_J, R, r)$ corresponds to the first moment of jet energy functions.

Light Quark and Gluon Jet Results

The Jet Energy Profiles for light quarks and gluons were originally calculated by colaborators in arXiv:1206.1344

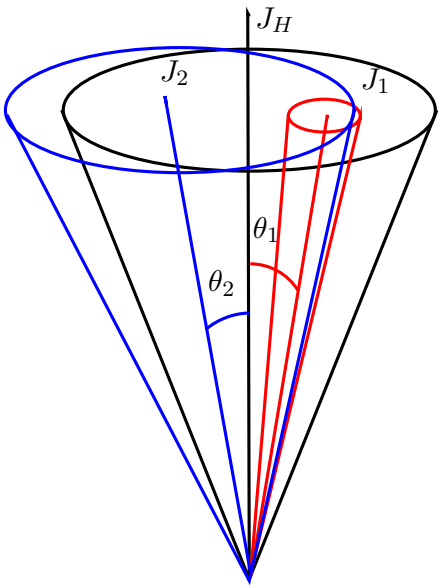


Factorization: Hard Kernel



Hardest scale physics determined by the decay of the Higgs, or other electroweak bosons

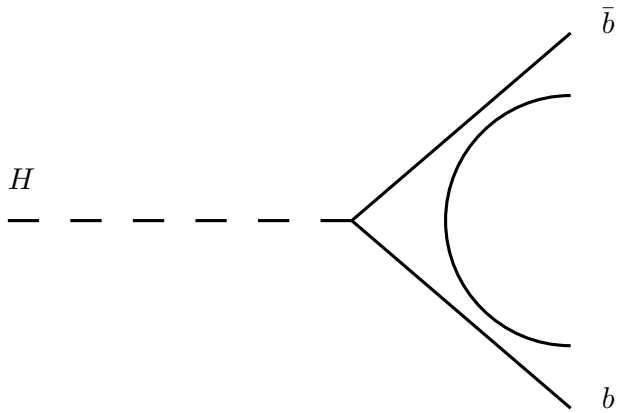
Factorization: Jet Functions



Factorize collinear physics:

- Two subjets
- One thin jet
- One fat jet
- Need to introduce overlap parameter (factorization scheme)

Factorization: Soft Function



Factorize Soft Radiation:

- Gluons radiate between the two quark lines
- Energy of gluons much less than energy of the jet and of the subjets

Jet Energy Profile for $g \to gg$

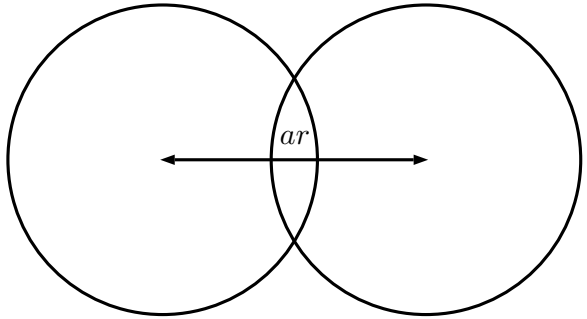
$g \to gg$ JEP

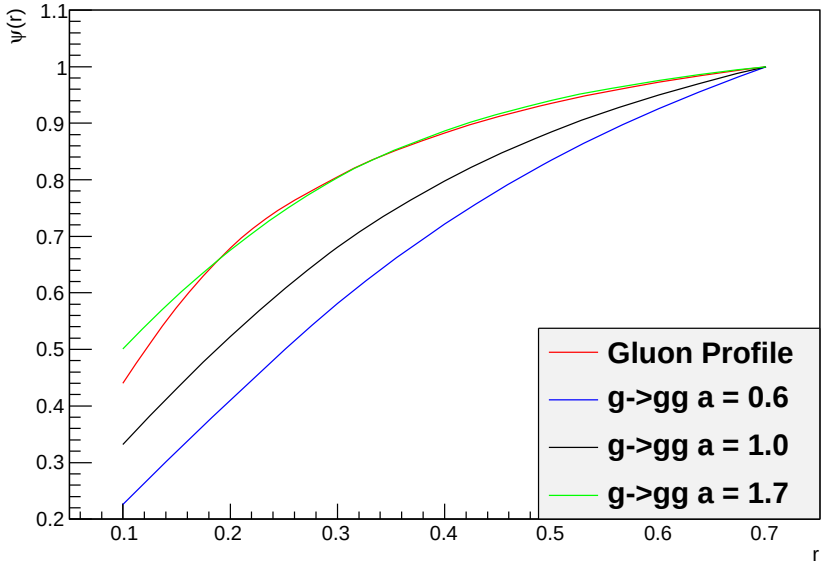
$$\bar{J}_g^E(1, E_{J_g}, R, r) = \frac{2}{R^2 (E_{J_g})^3} \frac{15\alpha_s(\mu)}{8\pi} \int dE_{J_1} \int d\cos\theta_{J_1} (E_{J_1} \cos\theta_{J_1} + E_{J_2} \cos\theta_{J_2}) \Theta(ar - \theta_{J_1}) \times \int dm_{J_2}^2 J_2(m_{J_2}^2, E_{J_2}, R) \frac{(E_{J_1})^2 E_{J_1} E_{J_2} [1 - \cos(\theta_{J_1} + \theta_{J_2})]}{\{2E_{J_1} E_{J_2} [1 - \cos(\theta_{J_1} + \theta_{J_2})] + m_{J_2}^2\}^2}$$

$E_{J_2} = E_{J_H} - E_{J_1}$, m_{J_2} is the jet mass for the fat jet

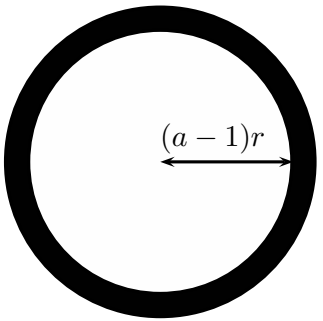
Choosing overlap parameter (a)

a defines the overlap parameter in our scheme, determining when to count the energy of the thin jet.





Taking azimuthal angle in account, area of overlap is the ring seen below.



Full Result for $H \to b\bar{b}$

Jet Energy Profile for $H \to b\bar{b}$

$$\bar{J}^{E}_{H}(1, E_{J_H}, R, r) = \frac{2}{R^2 (E_{J_H})^3} \frac{1}{\pi^2} \left(\frac{m_b}{v}\right)^2 \int dE_{J_1} \int d\cos\theta_{J_1}$$
$$(E_{J_1} \cos\theta_{J_1} + E_{J_2} \cos\theta_{J_2}) \Theta(ar - \theta_{J_1})$$
$$\times \int dm^2_{J_2} J_2(m^2_{J_2}, E_{J_2}, R)$$
$$\frac{(E_{J_1})^3 E_{J_2} [1 - \cos(\theta_{J_1} + \theta_{J_2})]}{\{2E_{J_1} E_{J_2} [1 - \cos(\theta_{J_1} + \theta_{J_2})] + m^2_{J_2} - m^2_H\}^2 + \Gamma^2_H m^2_H}$$

Approximate Form for $H \to b\bar{b}$

Approximations that are made:

- Take limit $\theta_{J_1} \to 0$
- Take $\lim_{\epsilon \to 0} \frac{1}{x^2+\epsilon^2} \approx \frac{\pi}{\epsilon}\delta(x)$ (Narrow width)

This leads to the following simple form for the Jet Energy Profile:

Jet Energy Profile Approximation for $H \to b\bar{b}$

$$\bar{J}_H^E(1, E_{J_H}, R, r) = \frac{m_b^2}{2\pi R^2 v^2} \frac{\hat{m}_H}{\Gamma_H} \int_{z_{\min}}^1 dz z(1-z),$$

With $\hat{m}_H \equiv m_H/E_{J_H}$, the variable $z = E_{J_1}/E_{J_H}$, and the lower bound $z_{\min} = \hat{m}_H^2/(\hat{m}_H^2 + a^2 r^2)$.

Comparison of Full Result to Approximate Result

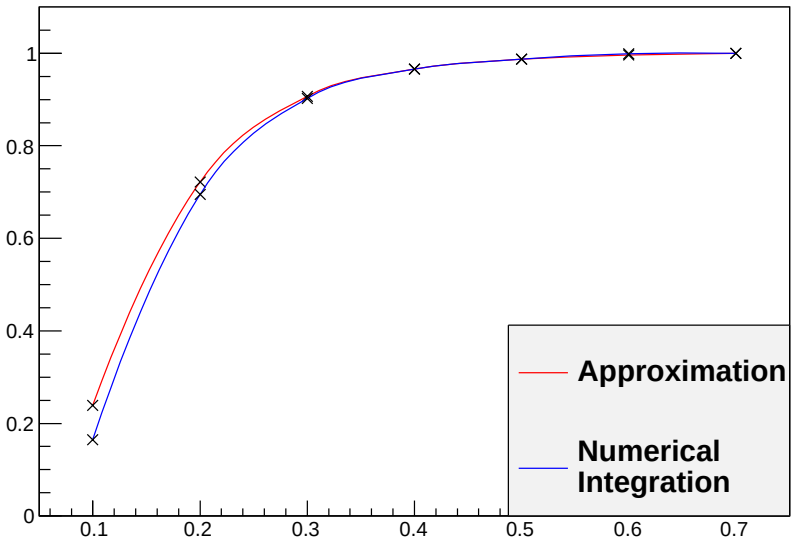
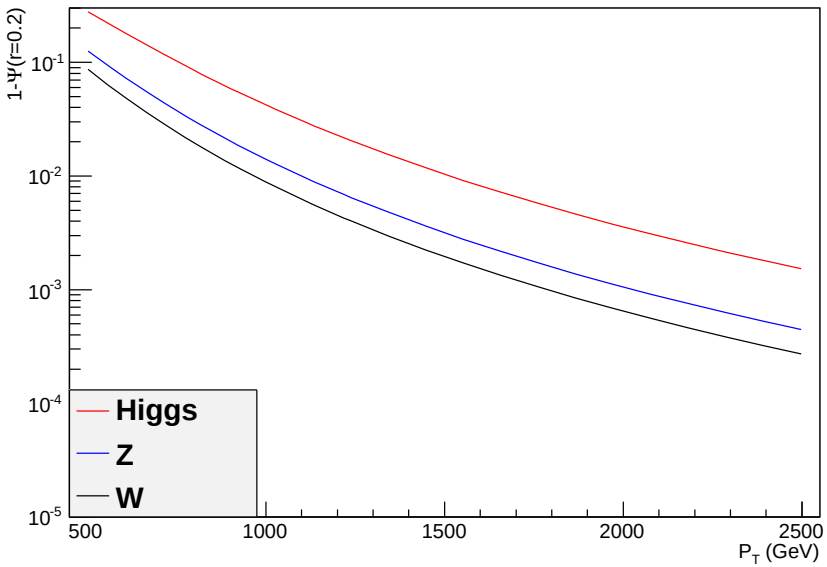
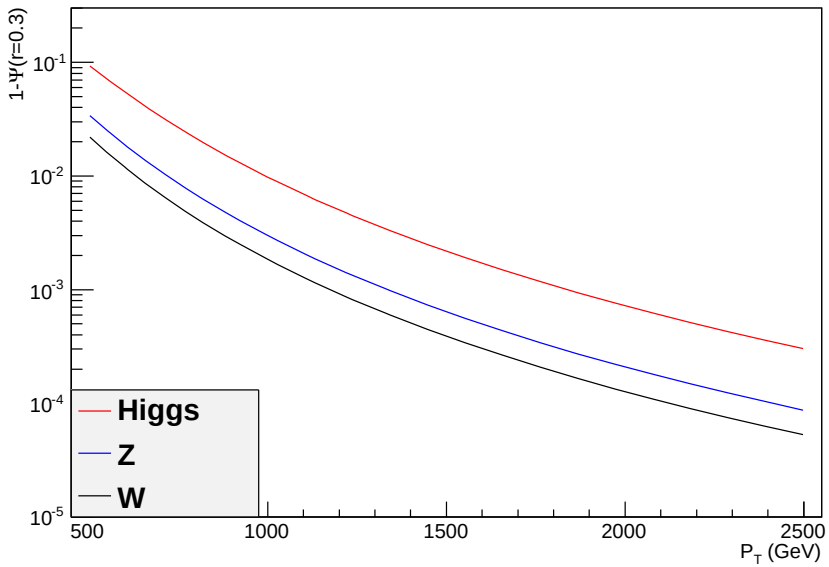


Figure : Numerical Calculation compared to Approximation for the Higgs Jets

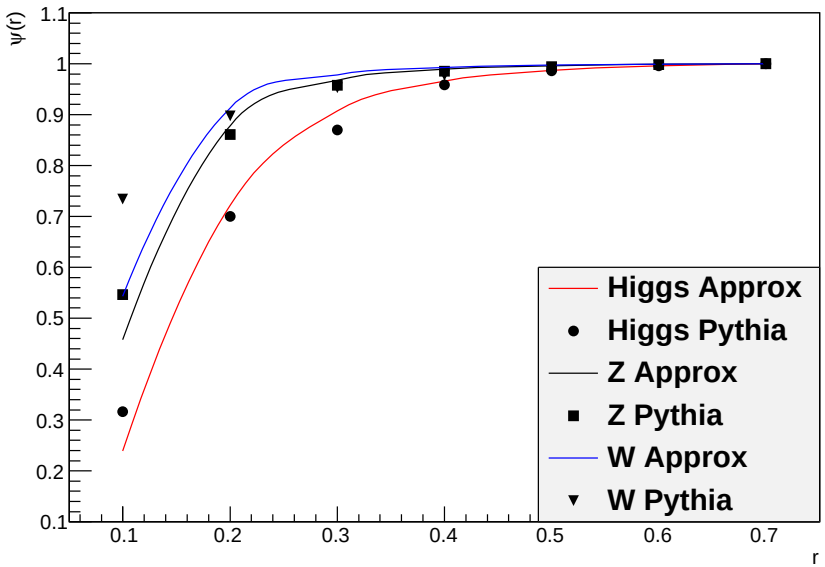
Energy Dependence of JEP





Comparison of Approximate Result to Pythia8 ATLAS Tune

Comparison of the approximation to the results from Pythia at 500 GeV



Conclusions

- Developed calculation for JEP for Electroweak bosons
- Found an approximate form for the JEP that can be used to calculate the profiles
- Future Developments:
  - Use the approximation to create a quick discriminator to distinguish between QCD, Higgs, W, and Z bosons.
  - Develop a FastJet plugin that can be used by experimentalists in Multivariate Analysis Methods.