The jet energy scale at ATLAS using Z+jet events

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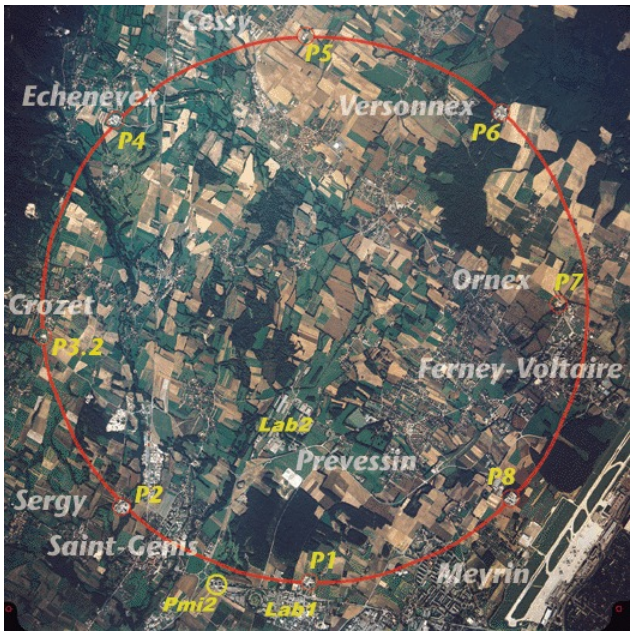
Introduction

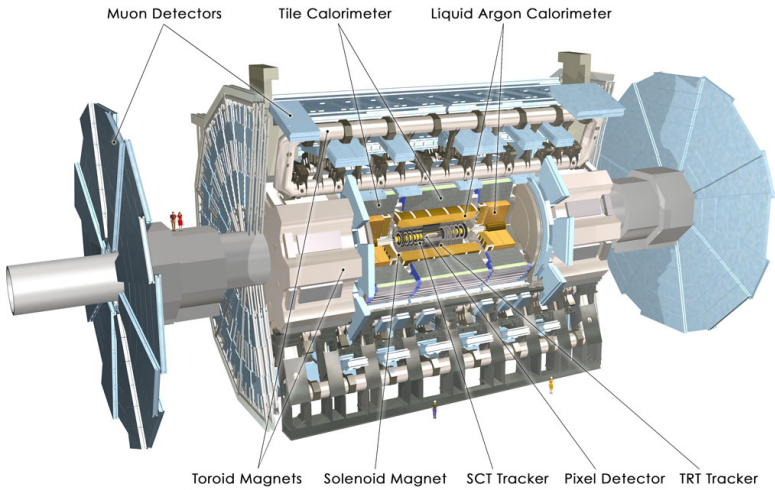
A quick reminder/lesson

The Large Hadron Collider (LHC)



27 km circumference storage ring collider
2010-2011 7 TeV centre of mass energy

A Toroidal LHC Apparatus (ATLAS)



LHC general purpose detector
44 m long x 25 m diameter

Introduction

Jets are collimated streams of particles

$\rightarrow$ Produced by hadronization of quarks and gluons

Jets are the most abundantly produced physics object at the LHC

$\rightarrow$ Important as both signal and background

$\rightarrow$ Necessary to accurately determine jet energy scale (JES)

Strategy

In-situ tag and probe methods used to determine JES

TAG well measured object

PROBE the recoiling system

Multiple variations being studied:

- γ+jet, with γ as tag
- Z+jet, with Z as tag
- dijet, central tag forward probe (calibrate different regions)
- multijet, low energy jets as tag, single high energy jet as probe

In this study Z+jet events are studied

MPF Method

Z+jet events used to determine response using Missing-E_t Projection Fraction (MPF) method

Uses:

- Imbalance in energy deposited in calorimeter (Missing-E_t or $\not\!\!E_T$)
- Well measured object balancing the jet (Z decaying to e^+e^-)

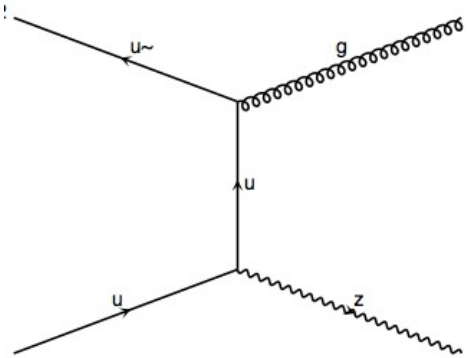
Advantages of using this method include:

- largely independent from jet algorithm
- resistant to pile-up activity
- resistant to initial and final state radiation

MPF Method

How does it work?

$\rightarrow$ Look at simple case



3 pieces of information:

- Balance at particle level
$$\vec{p}_T^{\,Z} + \vec{p}_T^{\,had} = \vec{0}$$
- Imbalance at detector level
$$R_Z \vec{p}_T^{\,Z} + R_{had} \vec{p}_T^{\,had} = \vec{\not{E}}_T$$
- Electron response well known (say $R_Z = 1$)

Together this gives

$$R_{had} = 1 + \frac{\vec{p}_T^{\,Z} \cdot \vec{\not{E}}_T}{\left|p_T^Z\right|^2}, \text{ where } MPF = \frac{\vec{p}_T^{\,Z} \cdot \vec{\not{E}}_T}{\left|p_T^Z\right|^2}$$

MPF Method

Extra activity may increase/decrease response event to event

Uncorrelated activity doesn't contribute *on average*

$\rightarrow$ Rules out pile-up

What about initial/final state radiation / the underlying event?

$\rightarrow$ Define a 'Missing transverse projection fraction' by

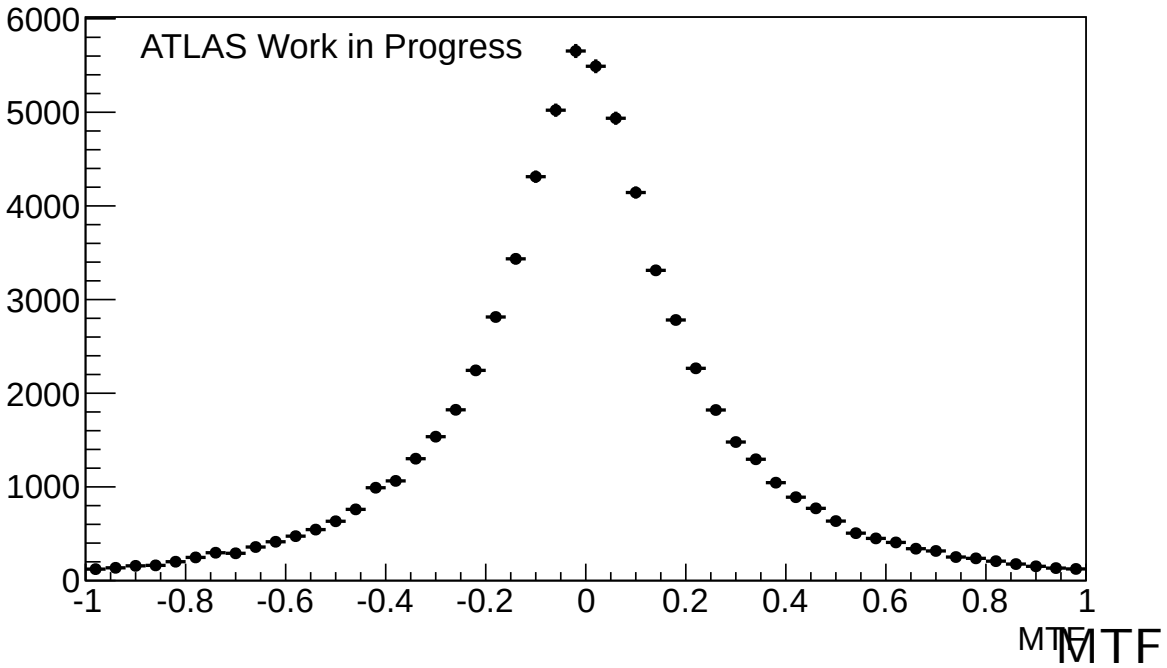
$$MTF = \frac{\left|\vec{p}_T^{\,Z} \times \vec{\not{E}}_T\right|}{\left|p_T^Z\right|^2}$$

Looks at activity perpendicular to the Z+jet

Should vary event by event but average to 0

MPF Method

How does it look?
Using $\approx$ 50 000 'good' Z+jet events (defined on next slide) from 2011 data:

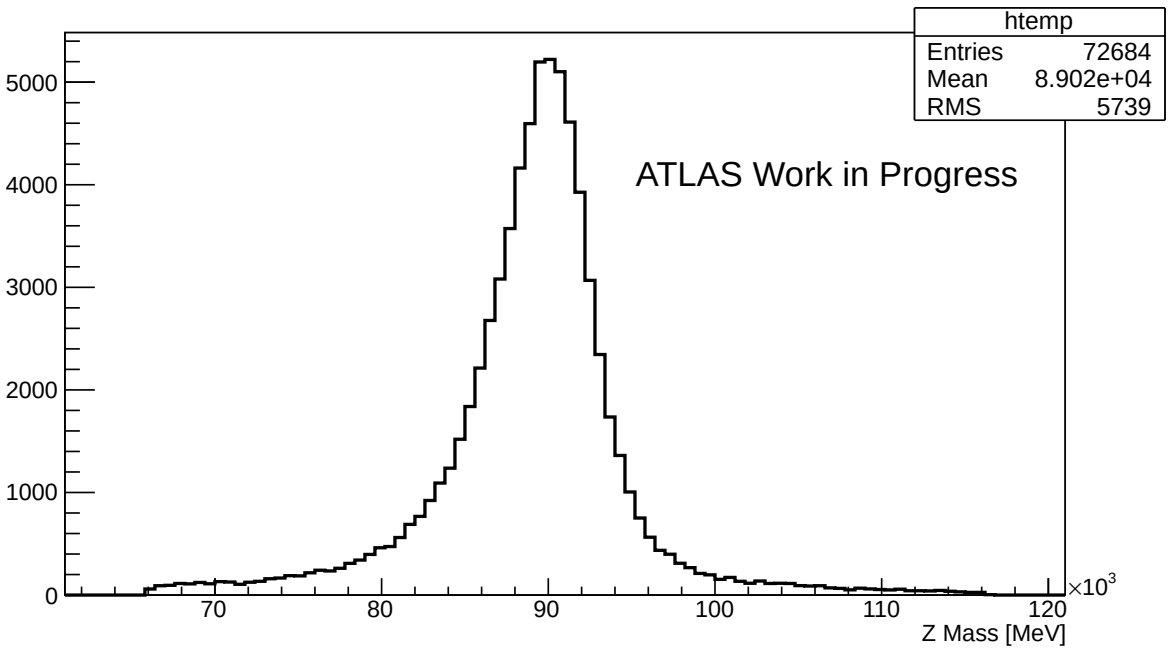


Average value of $\approx$ -0.002, no correlated source of MET perp. to jet

Event Selection

Z selection:

- 2 electrons (with extra quality cuts to ensure well measured electrons)
- opposite charges
- combined invariant mass between 66 and 116 GeV

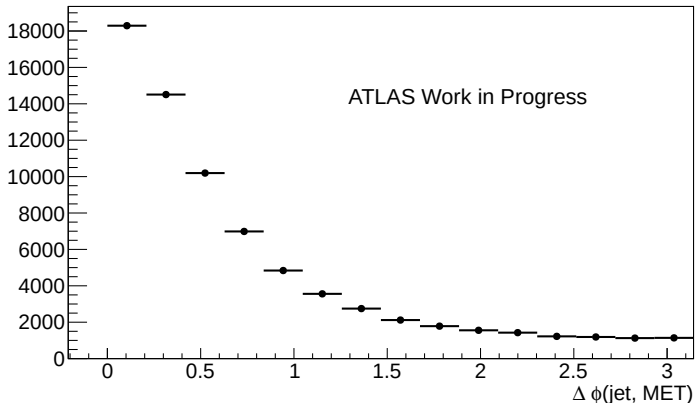


Event Selection

Jet selection:

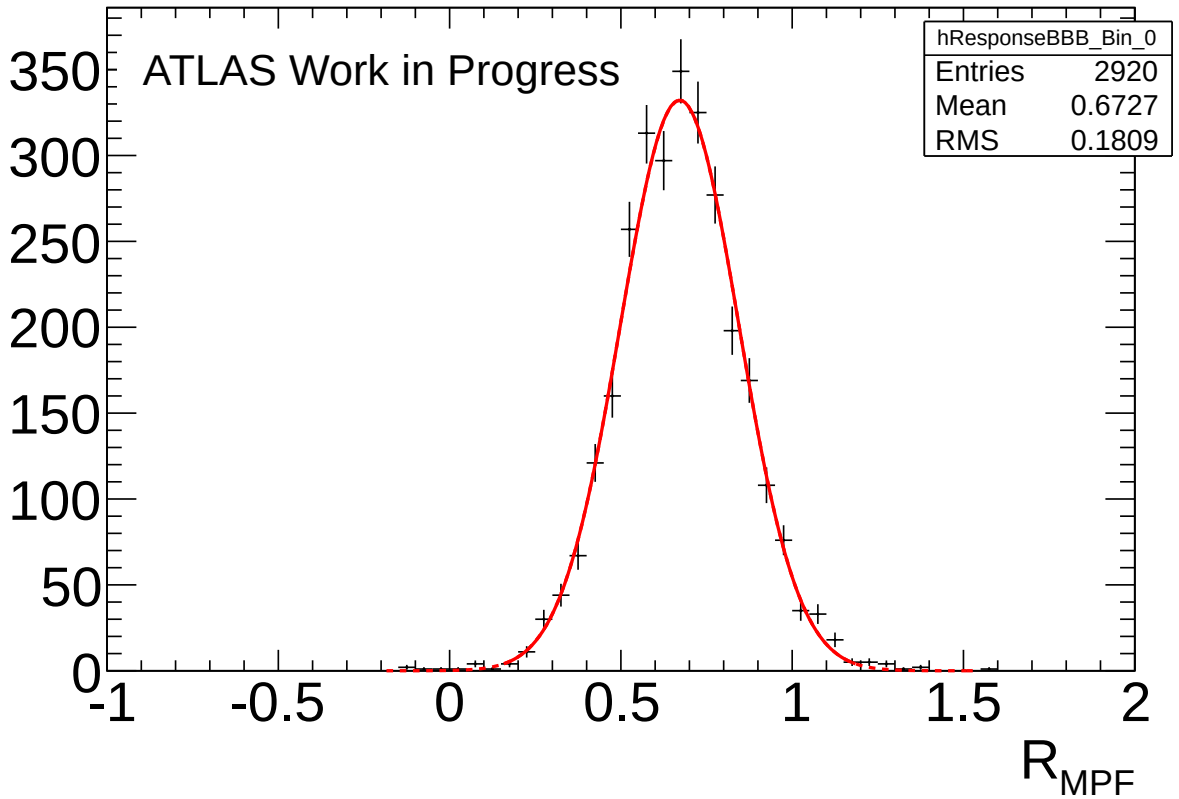
- At least 1 jet
- Leading jet in p_T isolated from electrons
- Leading jet $\eta < 0.8$ ($\theta < 42^\circ$)
- No secondary jets with $p_T > 0.3 p_T^Z$

Z and jet back to back ($\Delta(\phi)(Z, jet) > 2.9$)



MPF

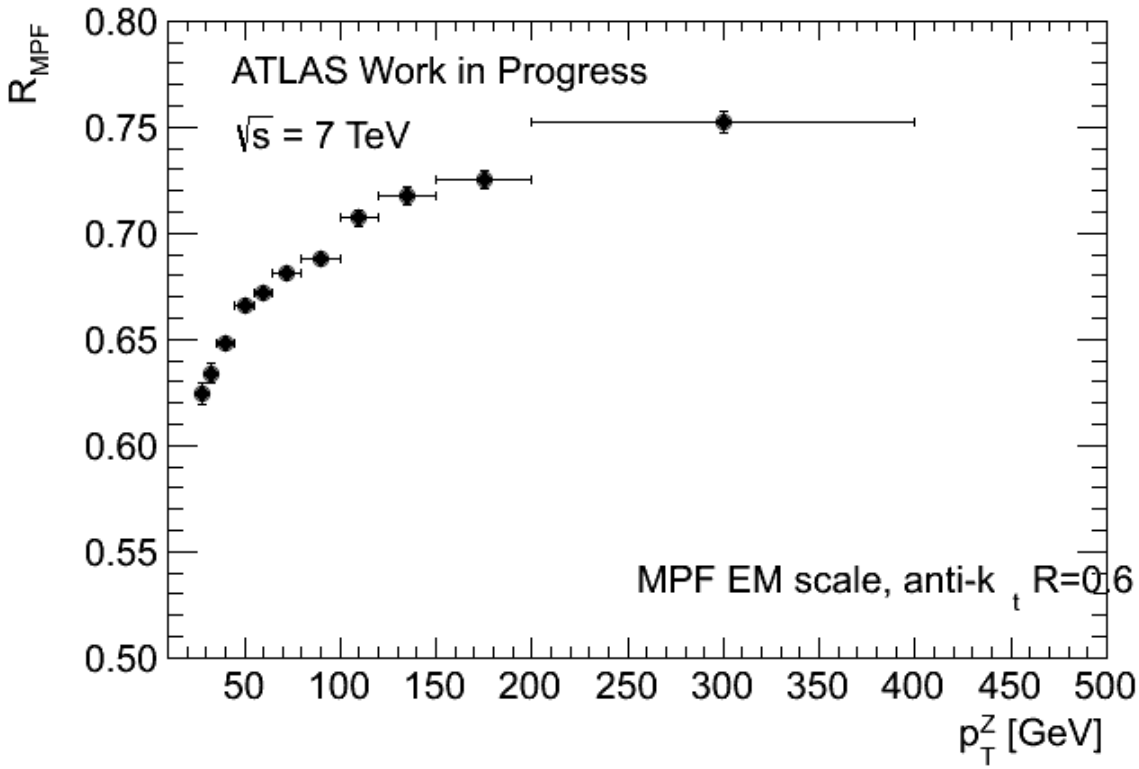
Events selected, looks at MPF distributions in p_T bins



Gaussian distribution with a clear mean

MPF

The result when it is all put together:



High energy jet $\rightarrow$ More π^0s $\rightarrow$ Higher response

What Next?

In-situ calibration dominated by γ+jet

Z+jet used to calibrate at low energies as γ+jet gets prescaled away
$\rightarrow$ Another advantage: different mixture of quark and gluon jets

Jets initiated by gluons should be wider and have a lower response
Seen when comparing γ+jet and dijet results

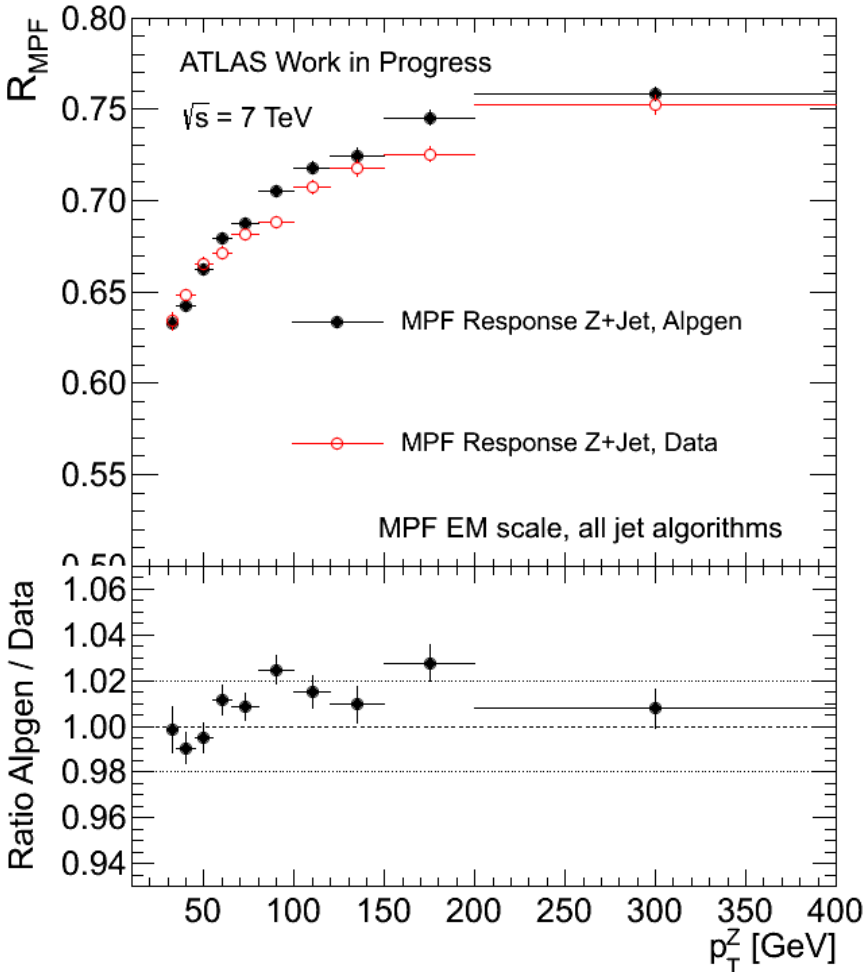
$\approx$ 5 % difference expected from previous studies

Should be possible to separate quark and gluon responses from γ/ Z+jet results

Separating Quark and Gluon Responses

Begin with Monte Carlo

How well does Monte Carlo model the response?

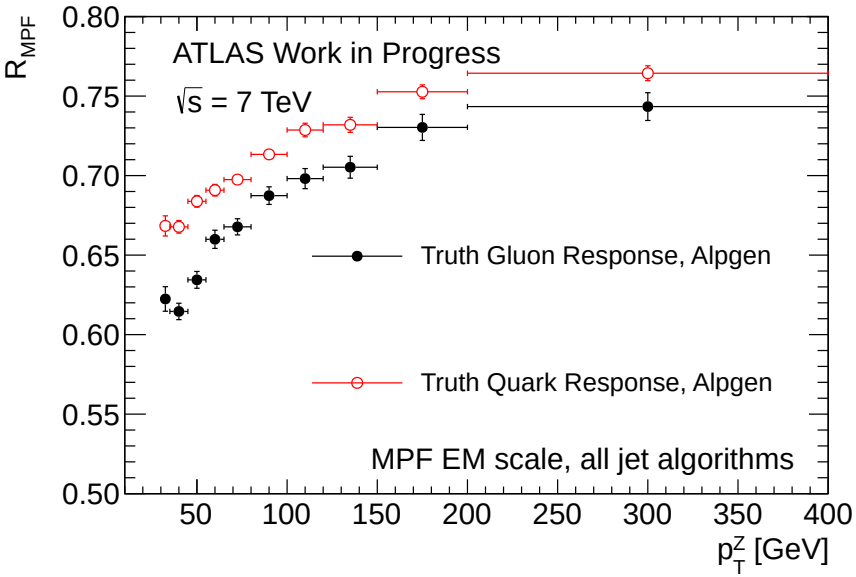


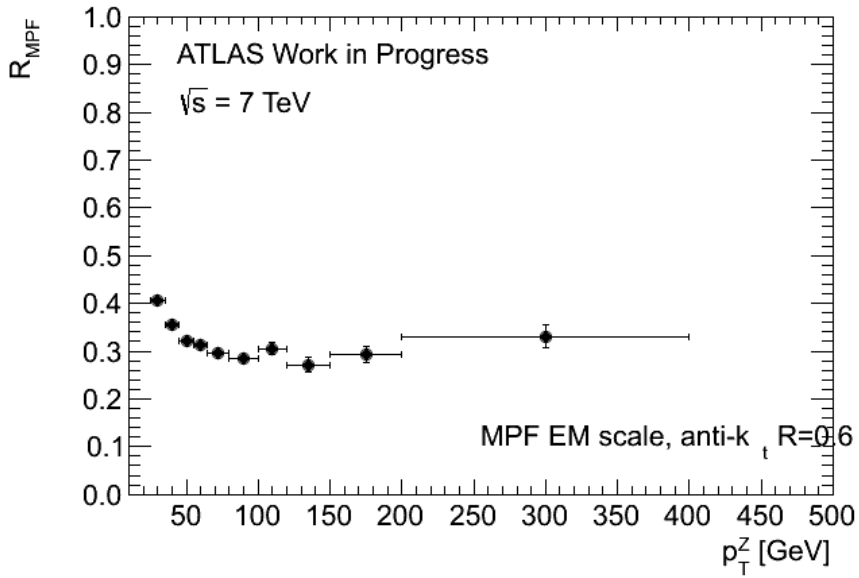
Separating Quark and Gluon Responses

Select highest p_T parton above 5 GeV near jet to tag as quark or gluon

Not all jets are tagged

$\rightarrow$ Will this affect the results?



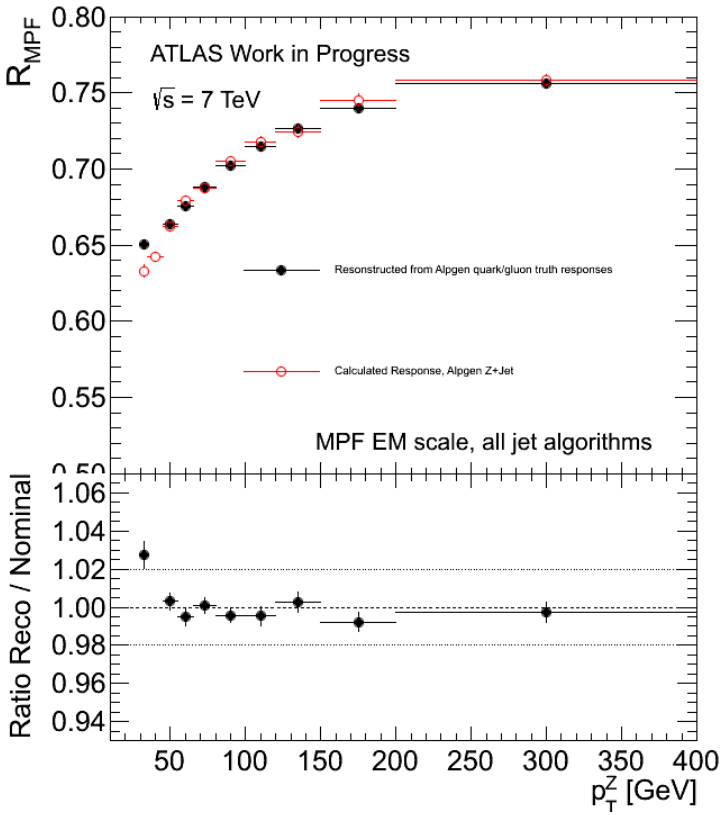


Response from Z should be given by:

$$R_Z = f_q^Z R_q + f_g^Z R_g$$

Separating Quark and Gluon Responses

Reconstruct Z response using these 'truth tagged' quark and gluon responses



Small differences caused by inefficiencies, not a large problem

Work in progress (more to come)