Calibrating jets for DELPHES software

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Outline

Motivations

- CERN experiments (ATLAS, CMS, ...) have fast simulation software that can only be used inside these collaborations.
- But phenomenological studies are not necessarily made in such collaborations.
  $\rightarrow$ **there is a need for free fast simulation softwares.**
- Sgluon studies (cf Monday's talk) made with DELPHES : a free detector fast simulation software (smearing and reconstruction of objects).
  `https://server06.fynu.ucl.ac.be/projects/delphes/wiki/WikiStart`
- Before using this software for the analysis, some checks have been done (*b*-tagging, energy scale of objets).

Motivations

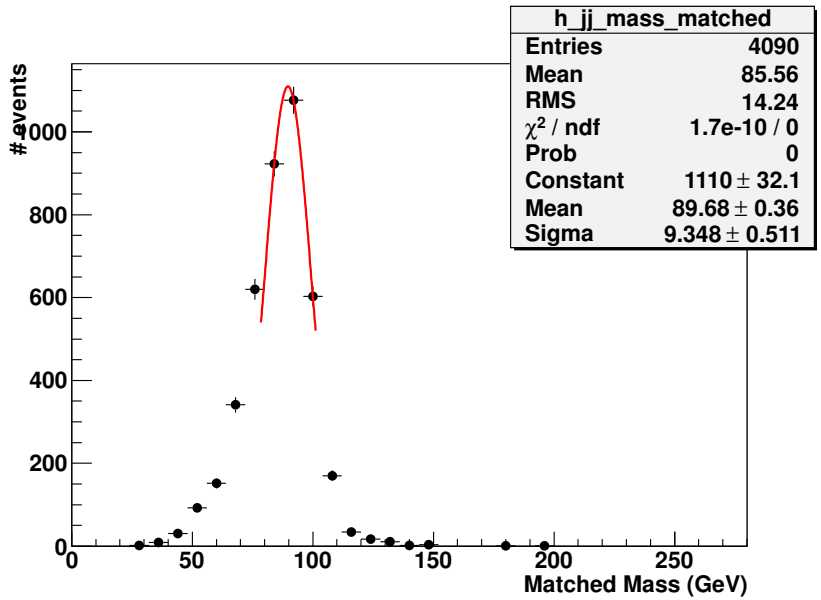
- We used $Z' \to jj$ (j only light jets) samples to perform cross-checks.
- The mass peak of Z' was not at the expected value (compared to MC truth) and it was shifted by several percents to lower values.
- To characterize this effect, we studied different Z' mass points.

The samples used in this study are produced by :

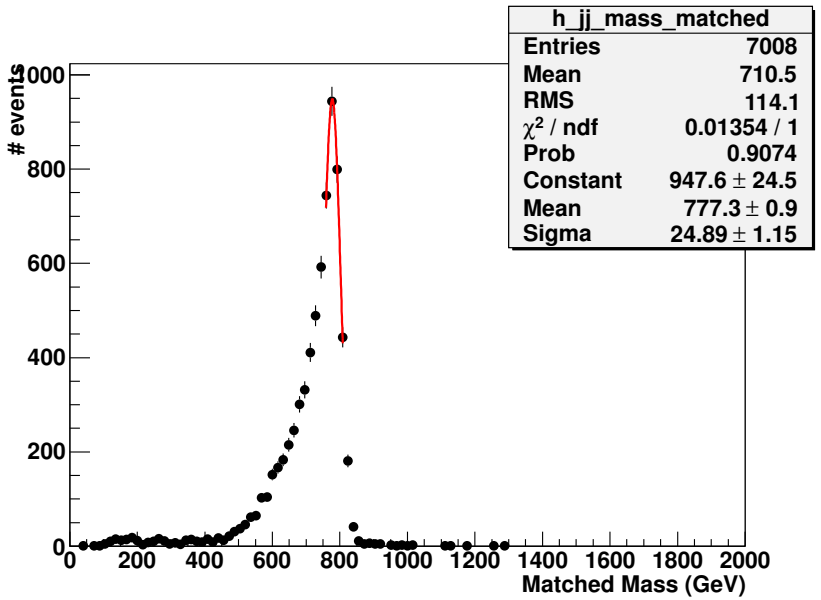
- MadGraph 5.1.2/5.1.3 for the parton level.
- Pythia6 for the parton showering and the hadronization.
- DELPHES for the detector simulation of ATLAS detector (jet algorithm anti-kT 0.4).

Examples

The selected events contains two jets (with $P_T \geq 5$ GeV) matched to the partons ($\Delta R \leq 0.4$) coming from the Z' decays.

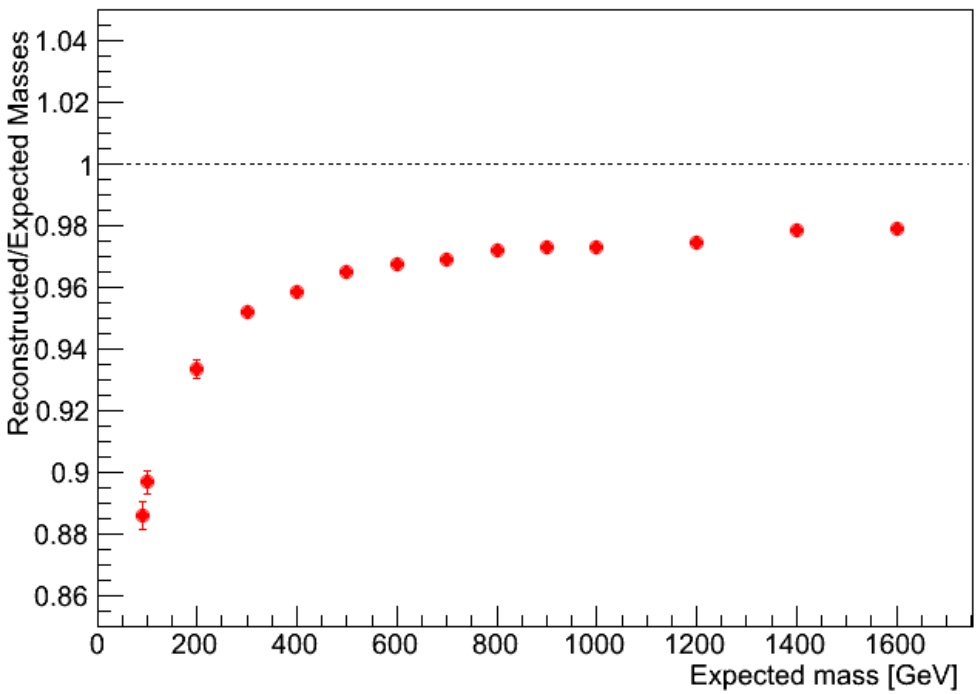


Z'(M=100 GeV)
Shift of $\sim$ 10%



Z'(M=800 GeV)
Shift of $\sim$ 2.8%

Generalisation - Summary



- The observed bias decreased with the mass of the considered Z'.
- Most probably, there is a dependance of this bias with respect to the energy of the jets.
  $\rightarrow$ **out-of-cone effect**
- To correct that, we will characterize the evolution of the bias with P_T of jets.

Introduction

The study will follow 4 steps :

1. Quantification of the effect
2. Modelisation of the effect - Correction extraction
3. Test of the correction
4. Propagation of the correction

Measurement of the bias

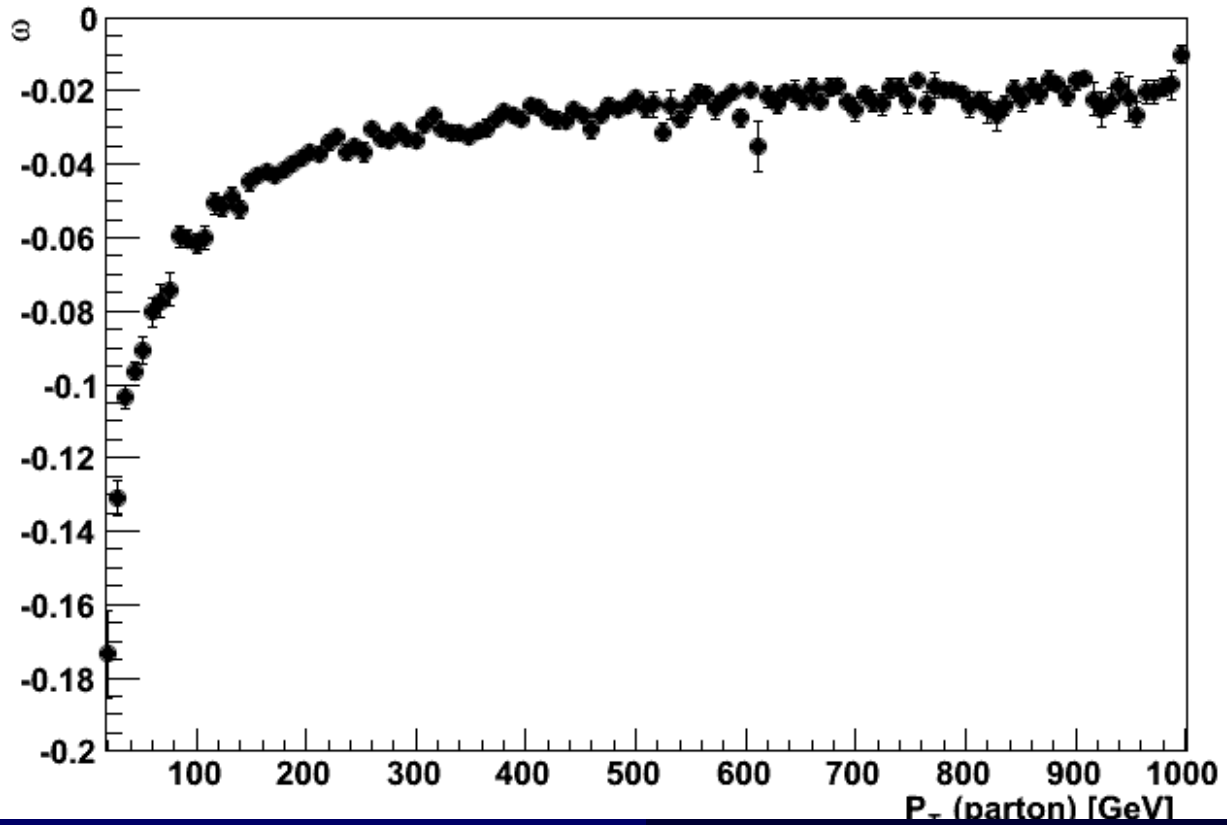
- Each parton coming from the Z' decay is matched to a reconstructed jet ($\Delta R \leq 0.4$).
- The difference between parton and corresponding reconstructed jet is parametrized by the variable ω :

$$\omega = \frac{P_T(\text{reco jet}) - P_T(\text{parton})}{P_T(\text{parton})}$$

- We then draw the distribution of ω with respect to $P_T(\text{parton})$.

Measurement of the bias

The distribution of $\omega = f(P_T(\text{parton}))$ for the combination of all the samples (from $M(Z') = 91$ GeV to $M(Z') = 2000$ GeV) is :

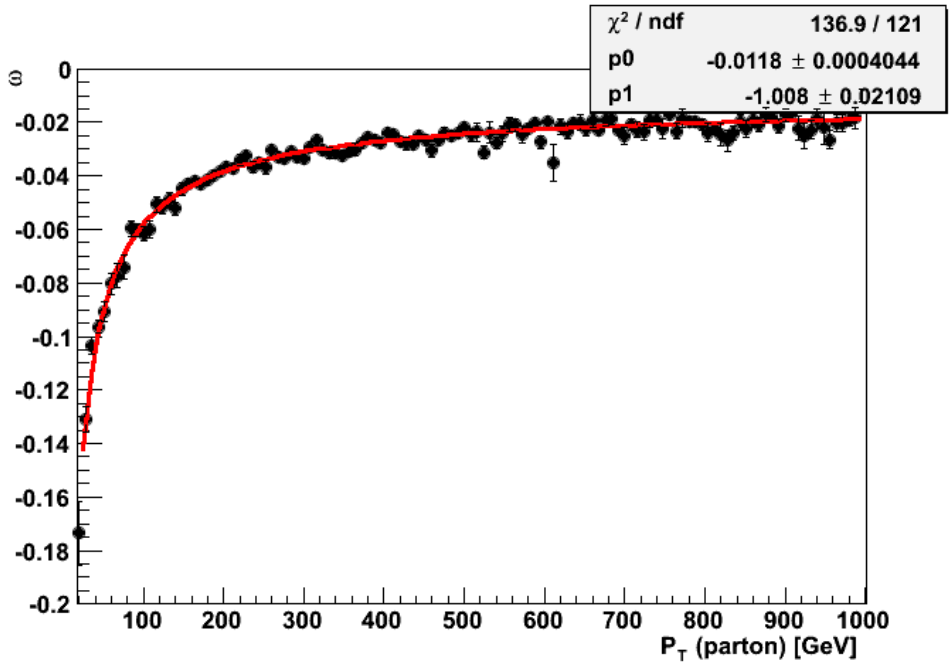


Fit function

- To obtain a continuous correction to apply for a given $P_T(\text{parton})$, we have to define a fit function verifying the criteria :
  - Convergent when $P_T(\text{parton}) \to \infty$.
  - Divergent when $P_T(\text{parton}) \to 0$.
- The chosen function is :

$$f(x) = a + b \times \frac{\ln(x)}{x}$$

where $x = P_T(\text{parton})$.



Modifying the horizontal axis

- The only value we can access at the reconstructed level is $P_T(\text{reco jet})$.
- We have to modify the horizontal axis to finally have $\omega = g(P_T(\text{reco jet}))$.
- To do so, we calculate, for a given $P_T(\text{parton})$, the corresponding $P_T(\text{reco jet})$ with the formula :

$$P_T(\text{reco jet}) = P_T(\text{parton})\,(1+\omega)$$

Modifying the horizontal axis

- The only value we can access at the reconstructed level is P_T(reco jet).
- We have to modify the horizontal axis to finally have $\omega = g(P_T(\text{reco jet}))$.
- To do so, we calculate, for a given P_T(parton), the corresponding P_T(reco jet) with the formula :

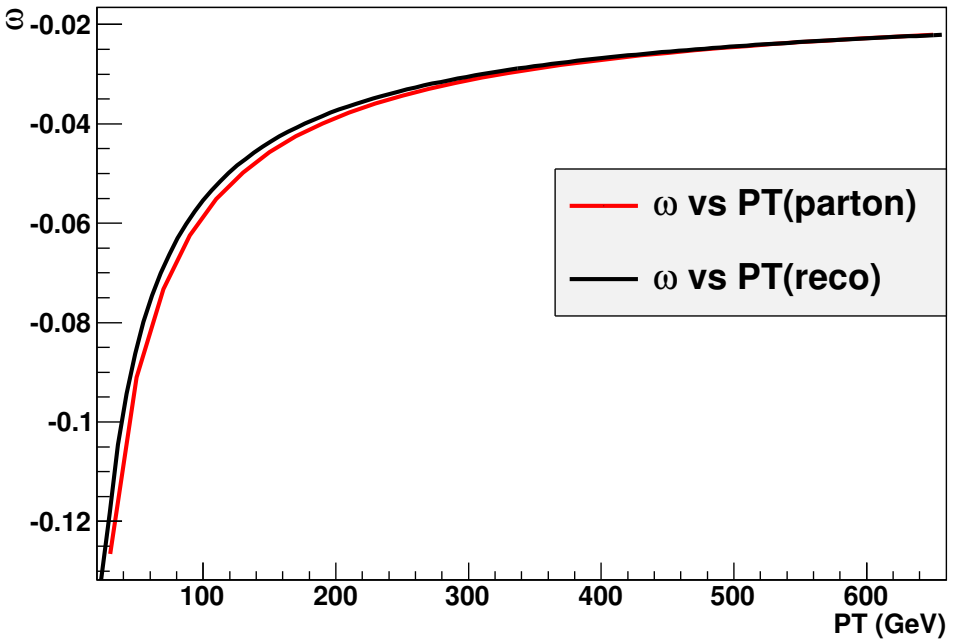
$$P_T(\text{reco jet}) = P_T(\text{parton})\,(1+\omega)$$

Example

Point **before** the modification of x axis : P$(P_T(\text{parton}); \omega)$
Point **after** the modification of x axis : P'$(P_T(\text{parton}) \times (1+\omega); \omega))$
Example :
$P_T(\text{parton}) = 200$ GeV $\rightarrow \omega = 0.04 \rightarrow P_T(\text{reco}) = 192$ GeV

Modifying the horizontal axis

The plot shows the distribution of ω vs P_T(parton) (red curve) and vs P_T(reco jet) (black curve).



- The fit function after the modification of the x axis is the same as before :

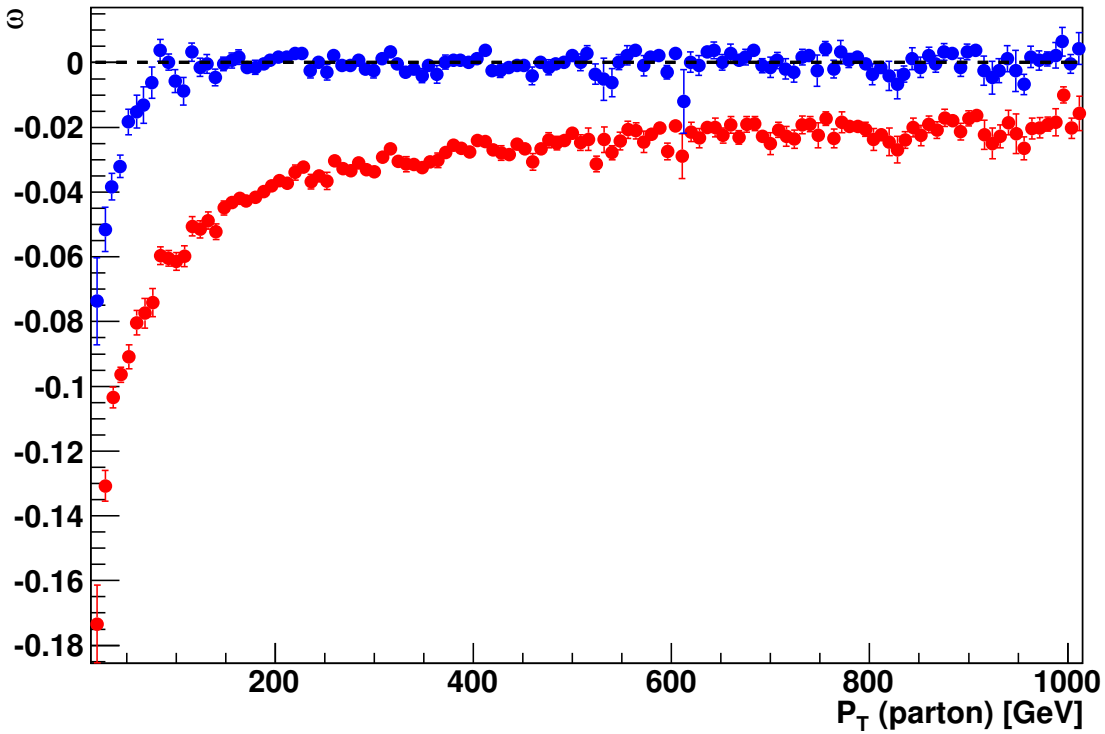
$$g(x) = a' + b' \times \frac{\ln(x)}{x}$$

- With the parameters :

$$\begin{cases} a' = -0.0127 \pm 0.0003 \\ b' = -0.92 \pm 0.01 \end{cases}$$

On the ω distribution

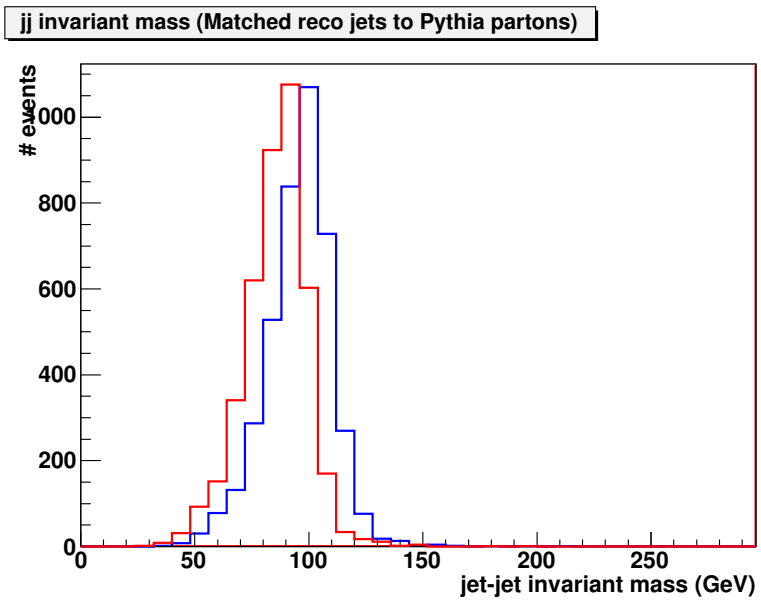
Omega distribution, before correction, and after correction.



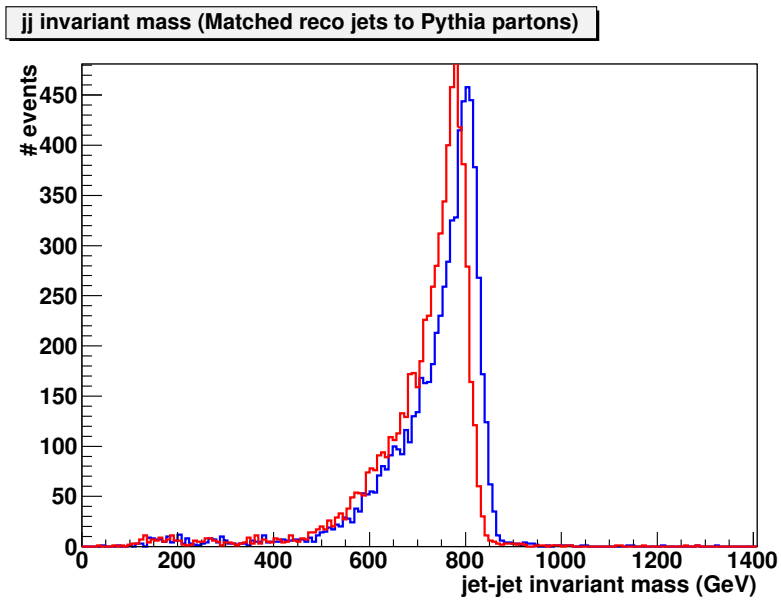
Overall good calibration after correction but at low P_T.

Examples

Before Correction After Correction

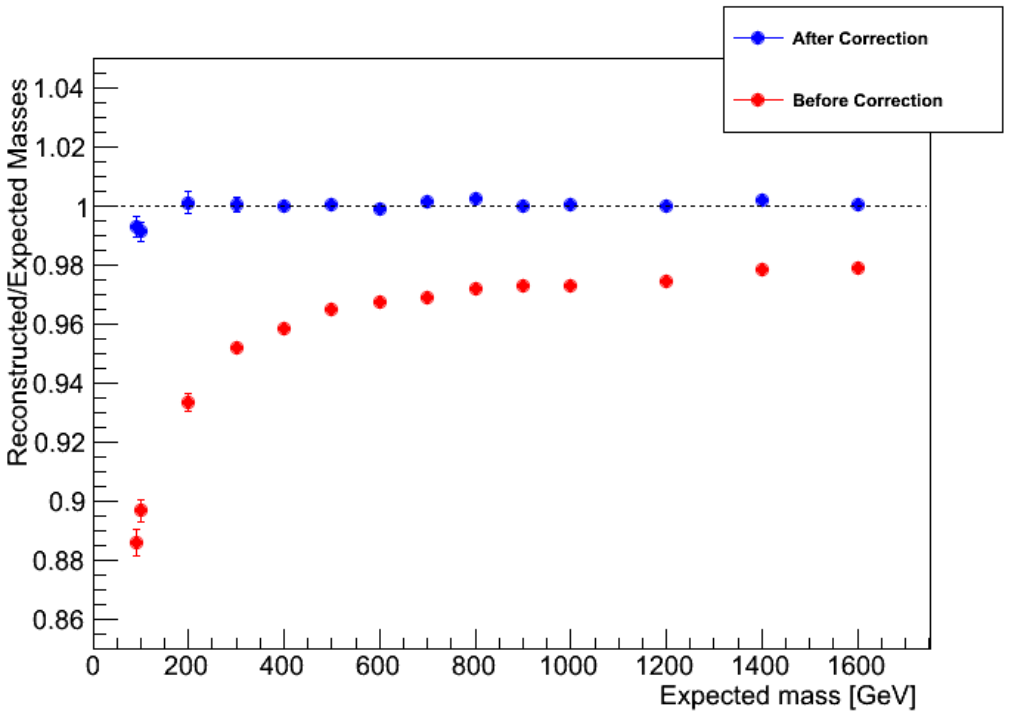


Z' (M=100 GeV)



Z' (M=800 GeV)

On the Z' masses



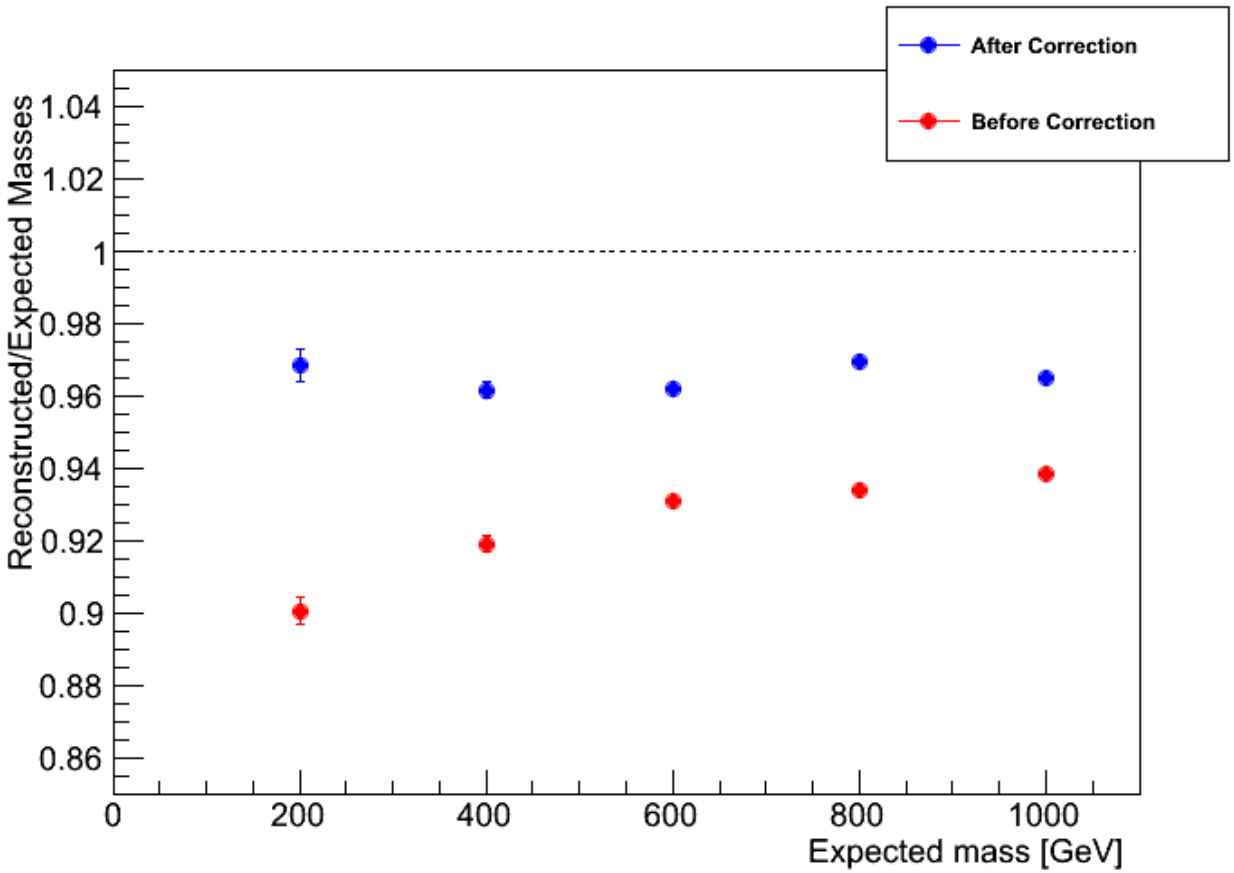
- The correction proposal seems efficient on the considered samples.
- After correction, the largest bias is around 0.6% obtained for low masses samples.
- But this calibration has only be done on light jets events

→ **what is the behaviour of this correction on b-jets ?**

Effect on b-jets

- The b-jets are expected to be wider than light jets, and the energy loss should be larger than for light jets due to the semi-leptonic decays.
- So the correction should not be sufficient to correct such jets.
- By the same simulation processes, $Z' \rightarrow b\bar{b}$ samples have been produced for 5 different mass points (200, 400, 600, 800 and 1000 GeV respectively).
- After correction, there is an offset of about 4%.

Correction effect on the *b*-jets



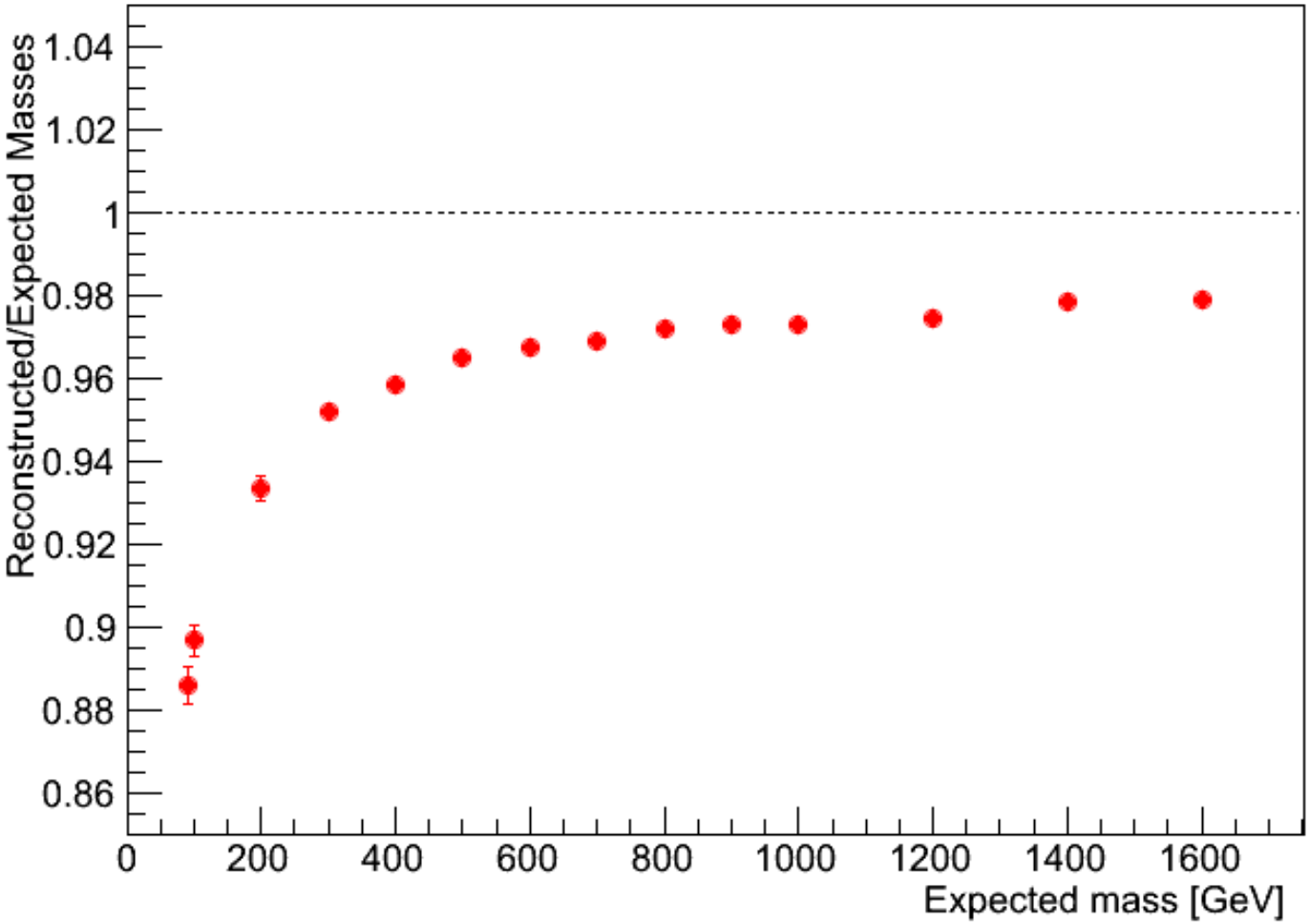
Conclusion

- We observed an energy loss in jets simulated by DELPHES software.
- This effect can be really important (10% of bias).
- But it can be corrected quite well using a parametrization of the response.
- After the correction the distributions are shifted to the expected values (maximum deviation after correction 0.6%).
- The propagation of this correction to *b*-jets gives an offset of around 4%, which could be due to the semi-leptonic decays.

BACKUP

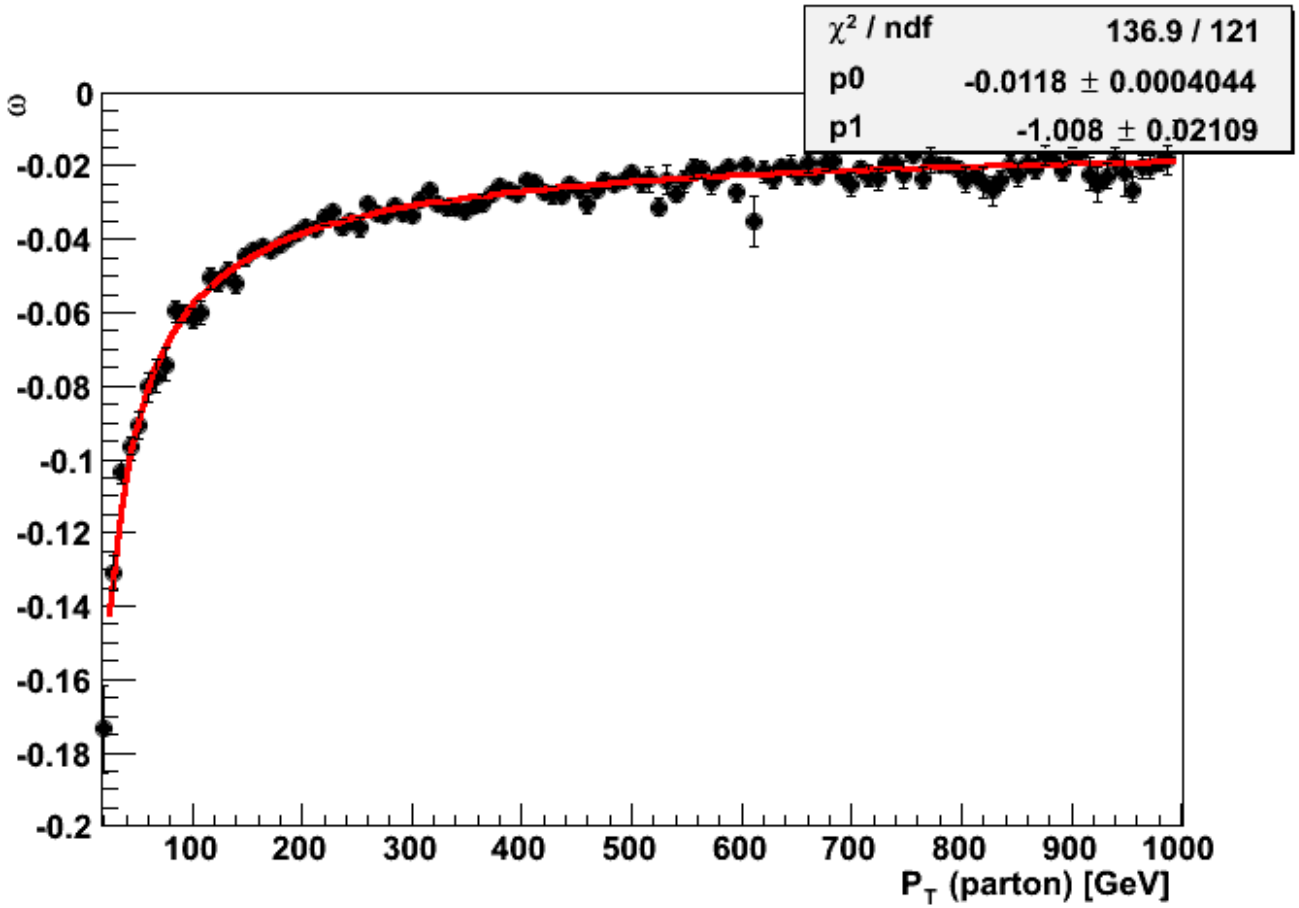
Backup 1

$$Ratio\ \frac{M_{reco}}{M_{expected}}\ distribution\ vs\ M_{expected}$$


Reconstructed/Expected Masses
1.04
1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0
200
400
600
800
1000
1200
1400
1600
Expected mass [GeV]

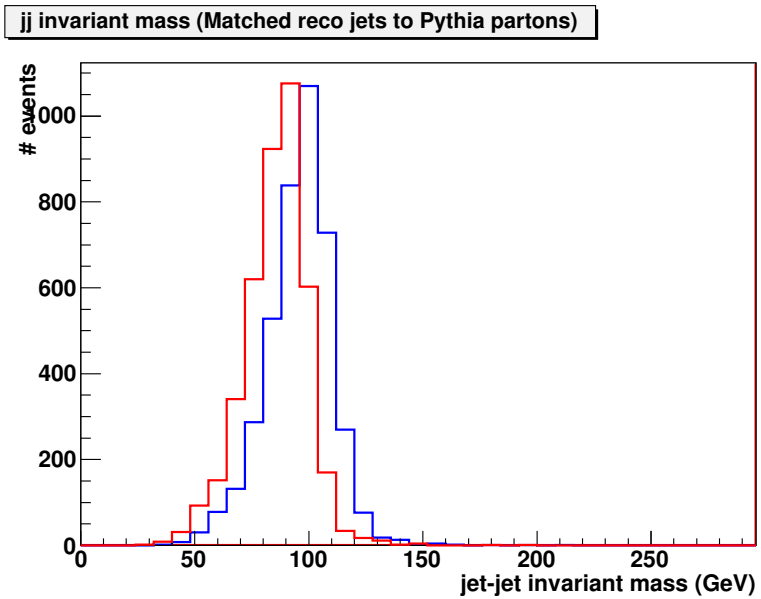
Backup 2

Distribution of ω vs P_T(parton)fitted

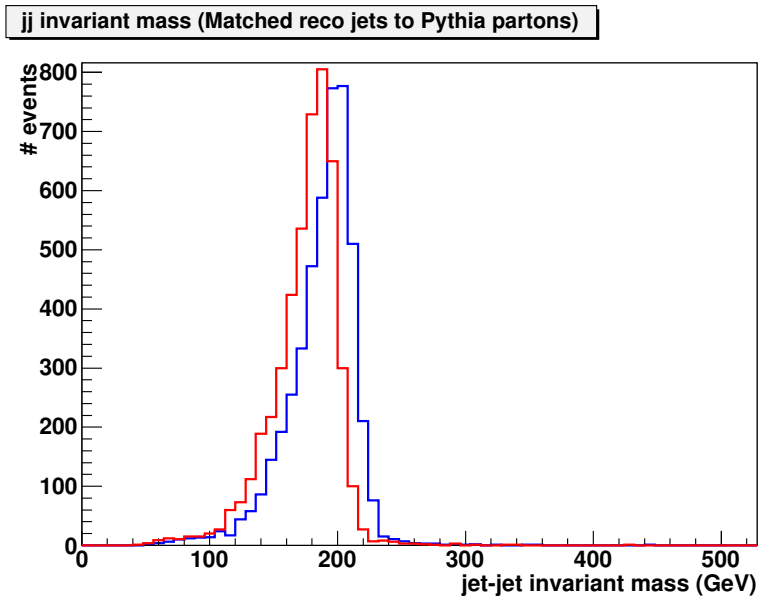

χ² / ndf 136.9 / 121
p0 -0.0118 ± 0.0004044
p1 -1.008 ± 0.02109
ω
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
-0.16
-0.18
-0.2
100
200
300
400
500
600
700
800
900
1000
P_T (parton) [GeV]

Backup 3

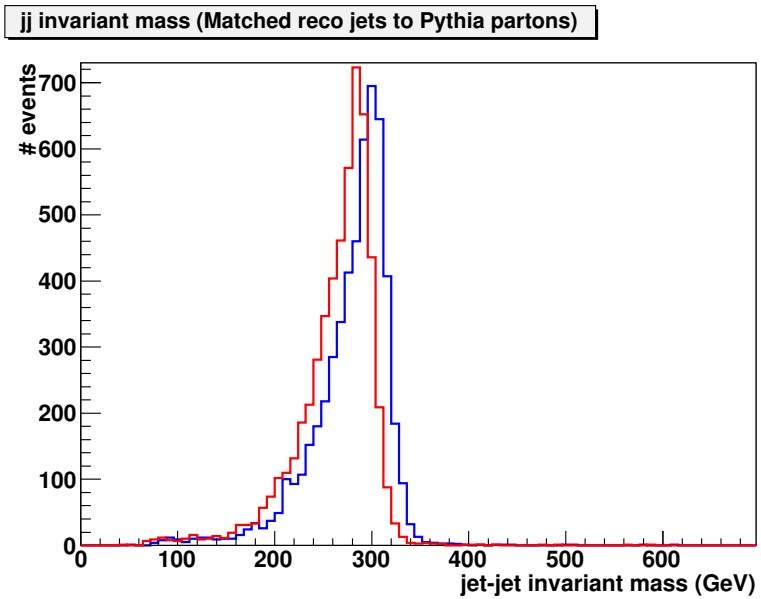
Distribution before after for all samples



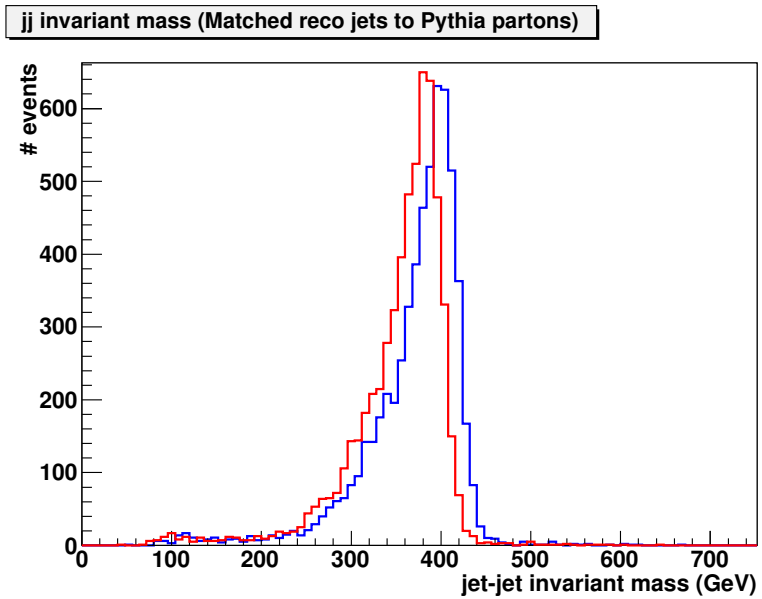
Z' (M=100 GeV)



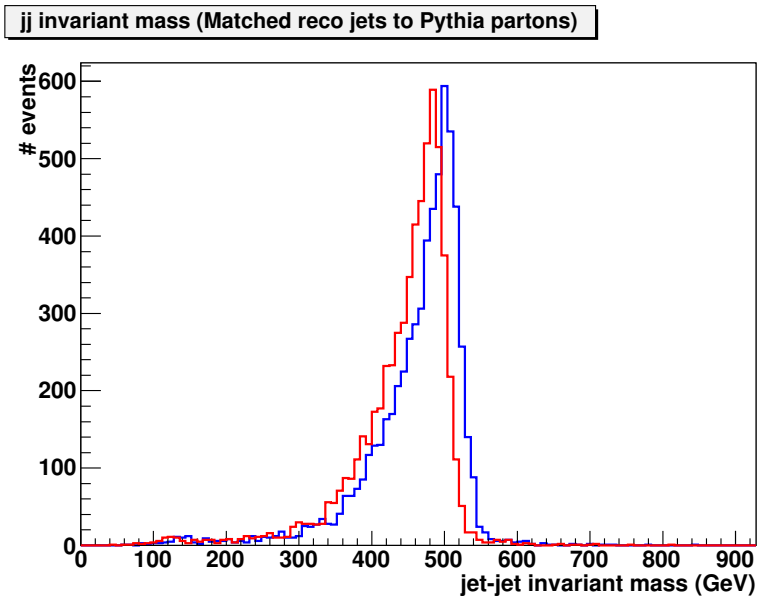
Z' (M=200 GeV)



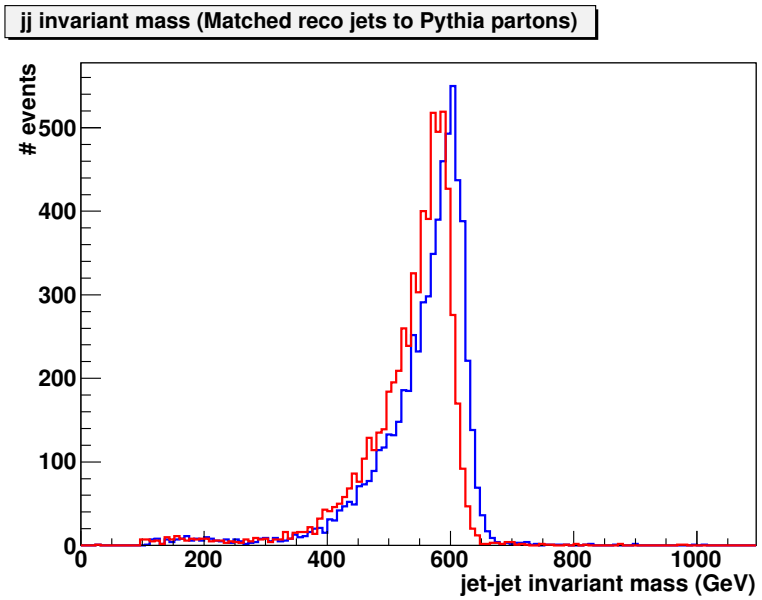
Z' (M=300 GeV)



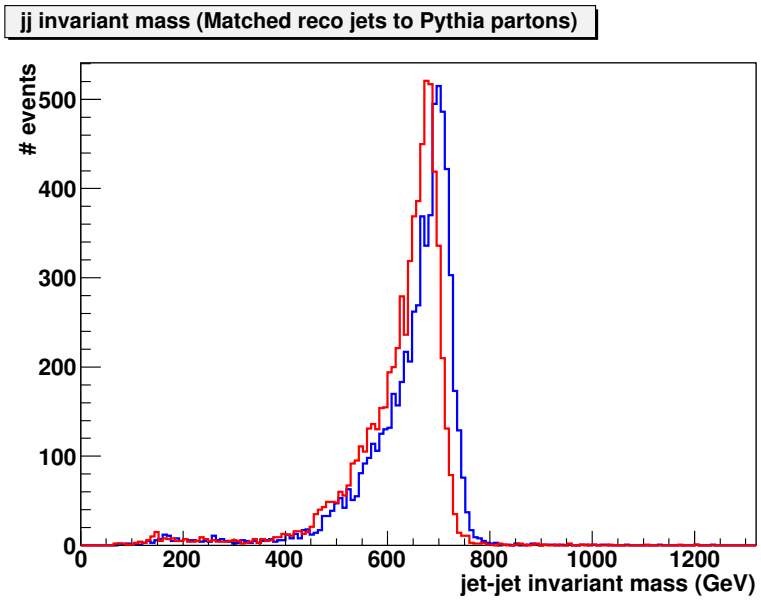
Z' (M=400 GeV)



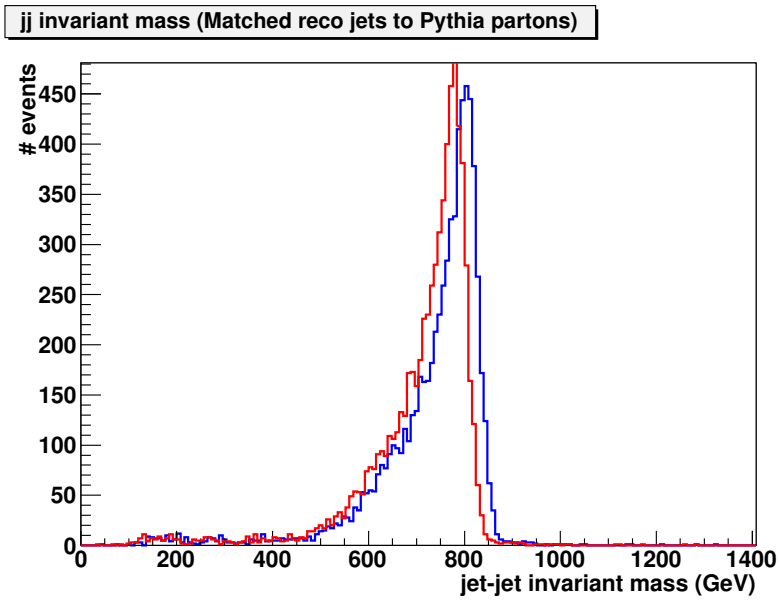
Z' (M=500 GeV)



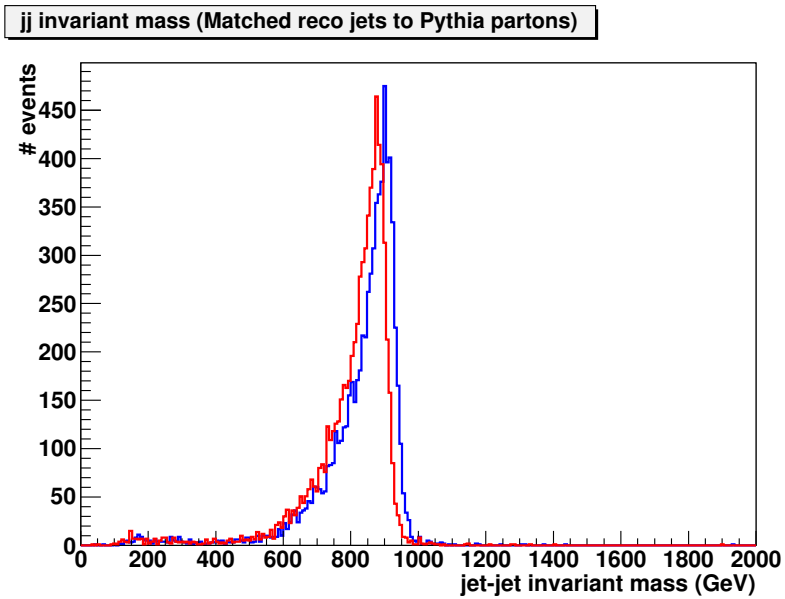
Z' (M=600 GeV)



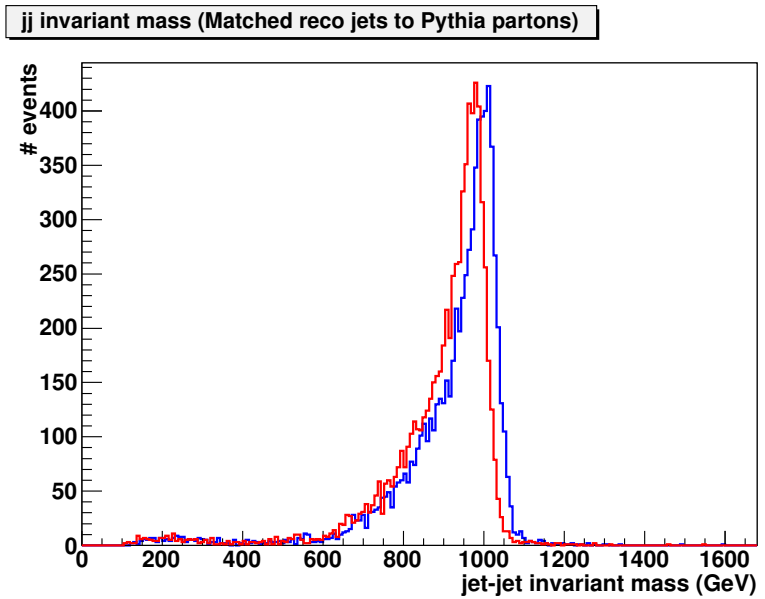
Z' (M=700 GeV)



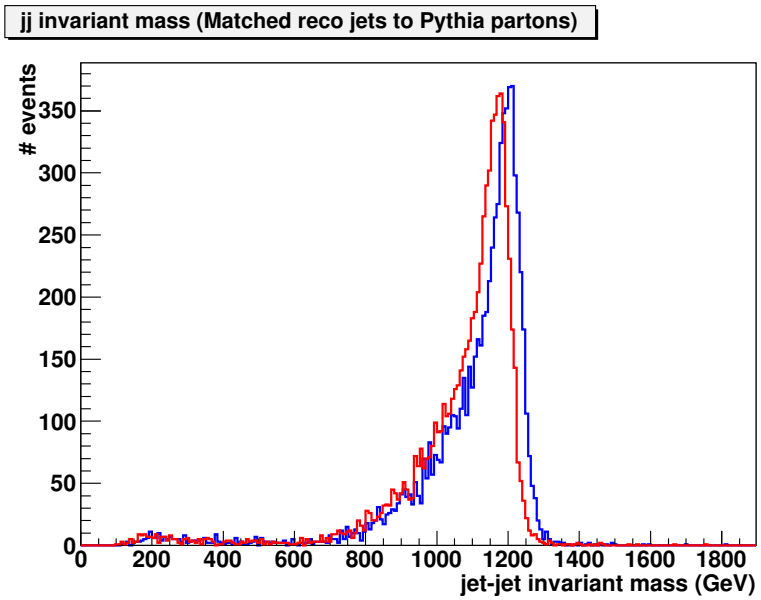
Z' (M=800 GeV)



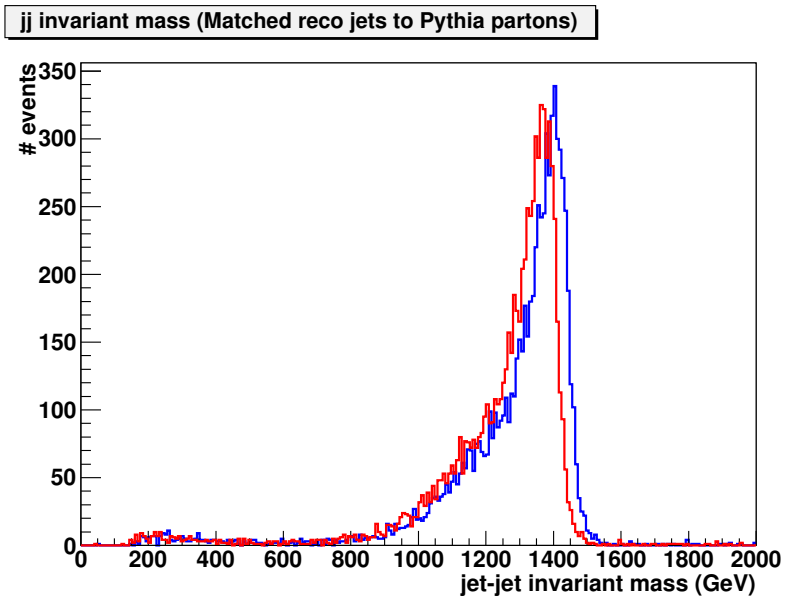
Z' (M=900 GeV)



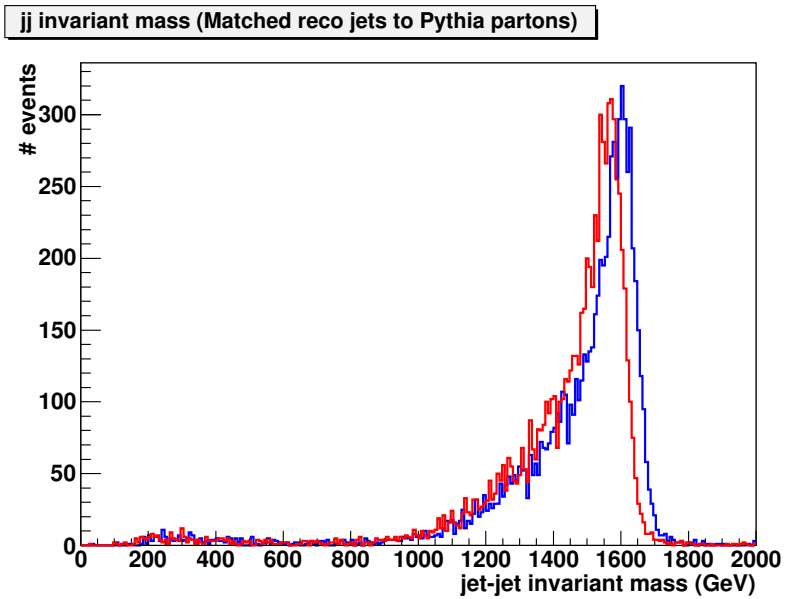
Z' (M=1000 GeV)



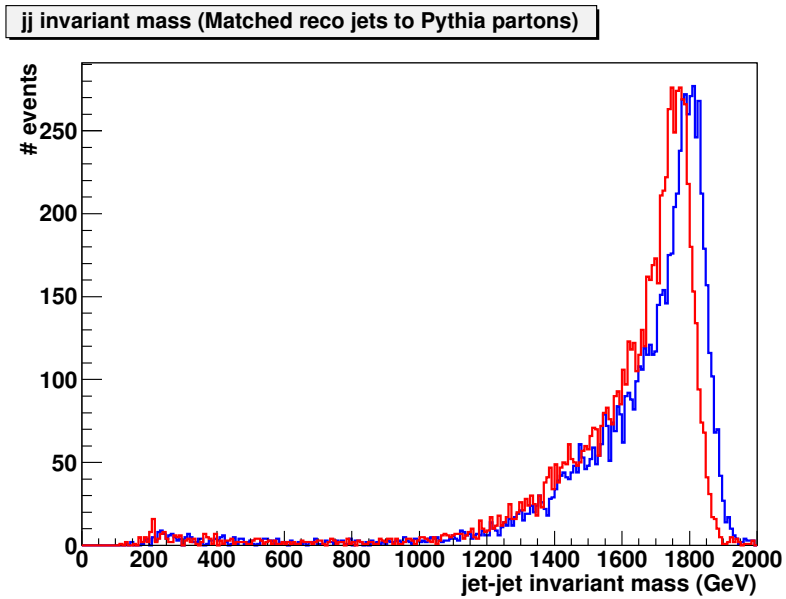
Z' (M=1200 GeV)



Z' (M=1400 GeV)



Z' (M=1600 GeV)



Z' (M=1800 GeV)