Towards a b-jet calibration in DØ

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- Response measurement with $\gamma +$ jets events.
- The MET projection method
- How to extract the b-jet response
- Summary

Jet energy scale

Purpose of the jet energy scale:

- Scale 'detector-level' energy to particle level energy

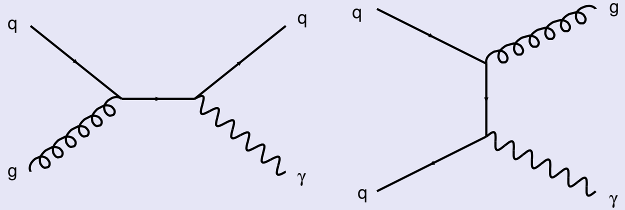
$$E_{jet} = \frac{E_{jet}^{meas} - E_0(\Delta R, \eta, L)}{R_{cone}(\Delta R, E, \eta) \times R_{jet}(\Delta R, E, \eta, \phi)}$$

- E_{jet}^{meas}: measured jet energy
- $E_0(\Delta R, \eta, L)$: offset (uranium noise, pile-up)
- $R_{cone}(\Delta R, E, \eta)$: fraction of energy inside cone with radius ΔR
- $R_{jet}(\Delta R, E, \eta, \phi)$: jet response in calorimeter

- This talk covers only jet response R_{jet}

Measuring the jet response

γ + jets events



- Response R_{jet} derived from γ+jets events using the Missing E_T Projection Fraction method (see slide 5)
- To minimze resolution bias, introduce energy estimator $E' = E_T^{\gamma} \cosh \eta_{jet}$
- Parameterization:
  $R_{jet} = p_0 + p_1 \ln\left(E_{jet}^{meas}/E_0\right) + p_2 \ln^2\left(E_{jet}^{meas}/E_0\right)$

Event selection

Jets:

- Run II cone jets with $\Delta R < 0.5$
- η regions: ECN: $-2.5 < \eta_{det} < -1.8$, CC: $|\eta_{det}| < 0.5$, ECS: $1.8 < \eta_{det} < 2.5$,

EMs:

- $N_{EM} = 1$, $p_T > 6$ GeV
- $|\eta_{det}| < 1.1$ or $1.6 < |\eta_{det}| < 2.5$, in fiducial, no trackmatch, HMX 7<12

General:

- EM and leading jet: $\Delta\phi > 3.1$
- no bad jets with $p_T > 8$ GeV
- one PV with at least 3 tracks, z withing 50 cm from center
- missingET cut (depends on p_T^{γ})

Event samples: about 40 M $\gamma +$ jets events:

The MPF method

MPF = Missing ET Projection Fraction Method

- use γ+jet(s) sample (back-to-back topology)
- ideal calorimeter: $\vec{E}_{T\,\gamma} + \vec{E}_{T\,had} = 0$
- real: $R_{em}\vec{E}_{T\,\gamma} + R_{had}\vec{E}_{T\,had} = -\vec{E}_T^{miss}$

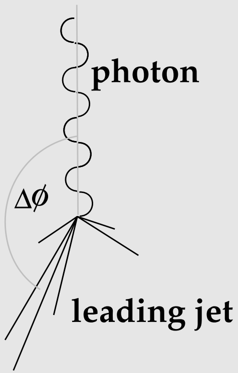
$$R_{had} = 1 + \frac{\vec{E}_T^{miss} \cdot \hat{n}_{T\,\gamma}}{E_{T\,\gamma}}$$

implies that em-scale is well known

- $R_{jet} = R_{jet}(E_{meas})$
- E_{meas} not well measured $\rightarrow$ bias due to jet resolution and steeply falling cross section

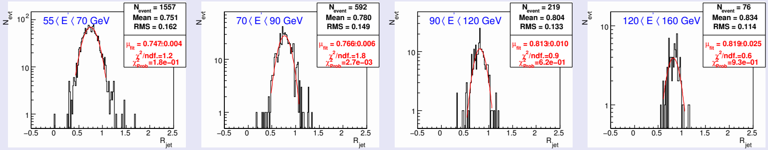
$\rightarrow$ bin in well measured quantities:

$$E' = E_{T\,\gamma}^{meas} \cdot \cosh(\eta_{jet})$$



plots by A. Kupčo

Response in E' bins



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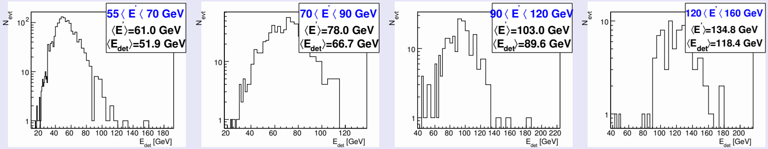
Jet energy in E' bins



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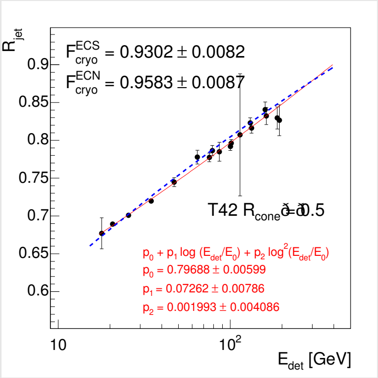
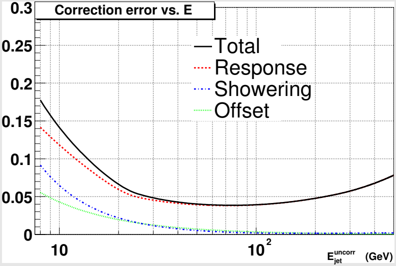
- Center of Gaussian fit to response curve gives y-coordinate
- Mean of energy distribution gives x-coordinate

plots by A. Kupčo

Response vs. detector energy



Uncertainties on total correction

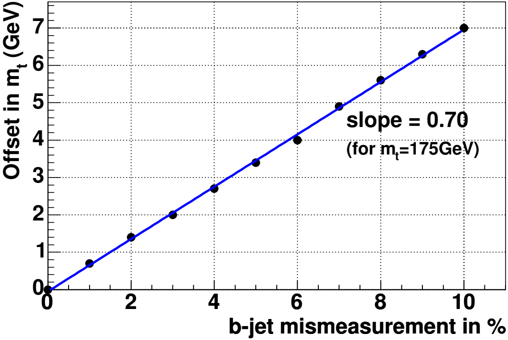


- Error on response dominant in central detector

Much improved JES uncertainties expected for the future

Why we must care about b-jet scale

- Correct jet energy scale is crucial for all analyses
- Current situation in DØ: (non-semileptonic) b-jet scale is the same as for light jets
- But b-jet response might be different (e.g. from fragmentation)
- Uncertainty or shift translates directly into top mass



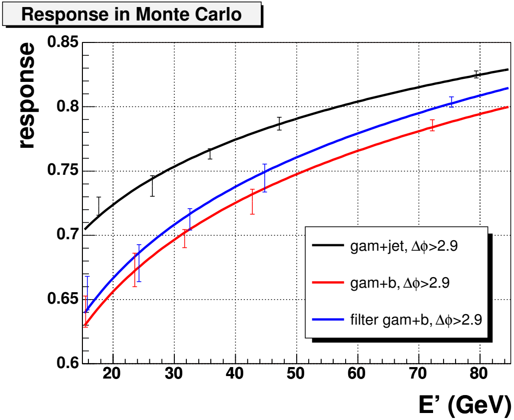
parton level

- . . . and for LHC: $H^0 \rightarrow b\bar{b}$ in WH^0 or $t\bar{t}H^0$!

What do we get from Monte Carlo?

Disclaimer: All following results are preliminary and still under study and not certified!

(Increase statistics by relaxing cut: $\Delta\phi > 2.9$)

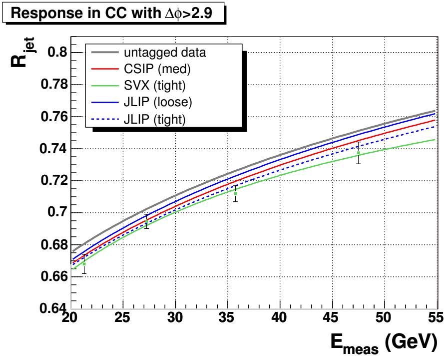


blue curve: semileptonic decays rejected

Response in tagged samples

Response for different lifetime taggers: CSIP, SVX, JLIP

$\Delta\phi > 2.9$, (relax the cut to increase statistics)

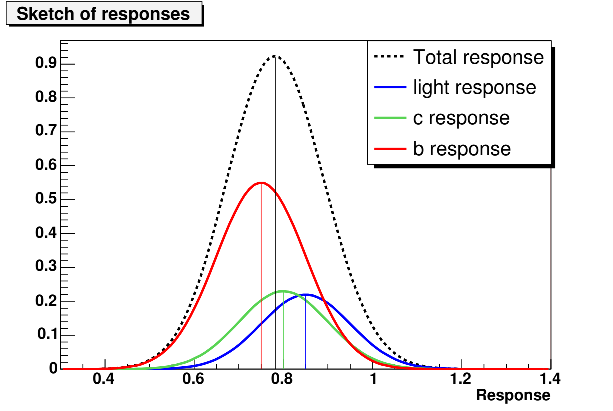


To give an idea of stat. errors, the data points for SVX are shown in the plots.

- Different taggers work at different operation points
  $\rightarrow$ different efficiencies and purities $\rightarrow$ different responses
- ►need pure b-response

Disentangling response

In tagged samples, R_t is a mixture of responses of $\gamma + b$, $\gamma + c$ and mistagged γ+light jets events



We are interested in the b-jet response.

Extracting response of b-jets R_b

In each E' bin solve a system of equations

$$\begin{aligned} \text{untagged:} \quad R_{ut} &\approx R_l && (1) \\ \text{tagged:} \quad R_t &= f_l R_l + f_b R_b + f_c R_c && (2) \\ \text{tagged+mass tag:} \quad R_{mt} &= f'_l R_l + f'_b R_b + f'_c R_c && (3) \\ \sum_i f_i^{(')} &= 1 && (4) \end{aligned}$$

3 equations, 3 constrains, but statistics might be a problem.

$$\rightarrow R_b = \frac{1}{f_b - \frac{f_c}{f'_c} f'_b} \left[R_t - R_{ut} \left(f_l - \frac{f_c}{f'_c} f'_l \right) - R_{mt} \frac{f_c}{f'_c} \right] \qquad (5)$$

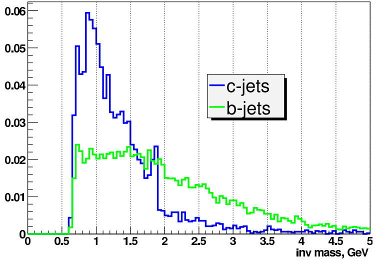
(R_{ut} = response in untagged samples, R_t = response in tagged samples, R_{mt} = response in tagged+mass tagged samples)

Must know proper flavor fractions f_i in the different samples.

The mass tag

(From a study by A. Khanov)

- in addition to lifetime tag, apply mass tag
- invariant mass of tracks with large DCA significance > 1.9 GeV

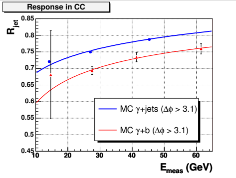


Efficiencies in EMqcd sample

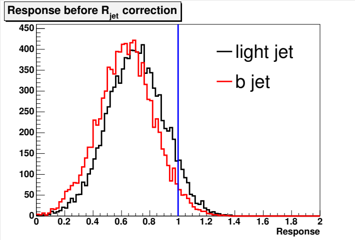
	b	c	light
CSIP	0.350	0.088	0.005
CSIP+mass tag	0.150	0.007	0.0007

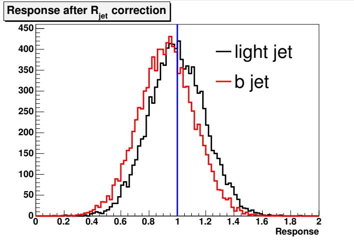
An approximative approach

At present, not enough statistics available to derive full energy dependence ($\sim$1000 events in tagged $\gamma +$ jets sample). Try a more inclusive approach as approximation.



1. derive energy dependent response function for light jets, assume $R_b(E)/R_l(E) = const_1$ and $R_c(E)/R_l(E) = const_2$
2. then need to derive only two scale factors $K_b = R_b/R_j$ and $K_c = R_c/R_j$
3. correct jets in untagged and tagged data by $R_{jet}(E)$
4. histogram inclusive corrected response $R_{untagged}$ and fit gauss $G_l(R)$ (should be centered at 1)

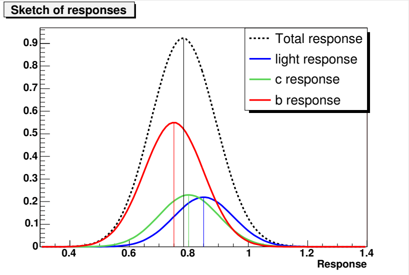




An approximative approach (continued)

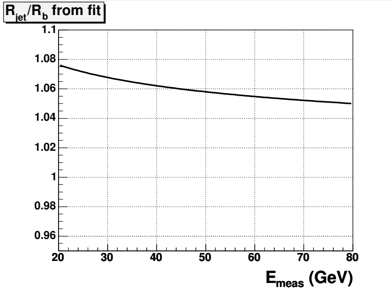
5. assume that distribution for b- and c-jets are the same except for scale factors K_b and K_c: $G_b(R) = G_l(K_b \cdot R)$
6. plot corrected response for tagged samples and fit

$$\text{fitfunc} = f_l \cdot G_l(R) + f_b \cdot G_l(K_b \cdot R) + f_c \cdot G_l(K_c \cdot R)$$

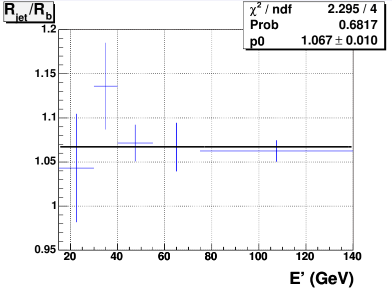


How flat is R_j/R_b in MC: γ+j and γ+b? ($\Delta\phi > 3.1$)

From fit vs. E_{meas}

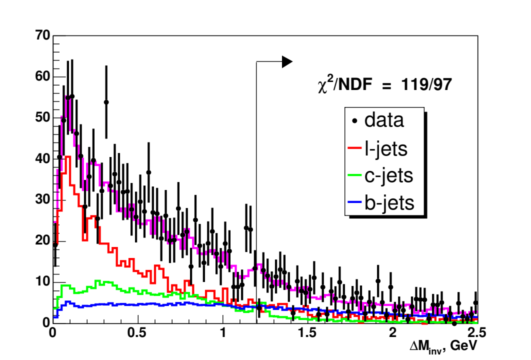


From response in E' bins



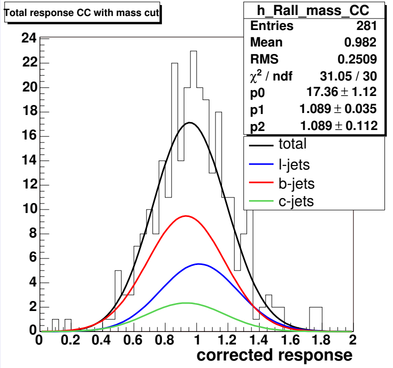
Flavor fraction fit/enhancing b-content

- Fractions after tagging f_l=50% f_c=24% f_b=26% (from template fit)
- Enhance b-fraction with additional cut on inv. mass of tagging tracks ($\Delta M_{inv} > 1.3$ GeV)
- Efficiency for mass cut:
  light=13% c=12% b=45%
- fractions after mass cut: f_l=32% f_c=13% f_b=55% much enhanced b content



Use: $f_l = 0.32, f_b = 0.55, f_c = 0.13$ (very preliminary estimate!)
$\Delta\phi > 3.1$

Inclusive – all energies



- $K_b = 0.92 \pm 0.03$
- $K_c = 0.92 \pm 0.09$
  (preliminary estimates)
- Correlations not taken into account in fit

K_b from Monte Carlo: ≈ 0.93–0.94

Conclusions

- Measurement of heavy flavor jet response has just started in DØ; detailed studies to be performed in the next months
- Important for top mass measurement
- Limited by statistics;
  full energy dependence of b-response not yet derived;
  but will improve very soon
- Cross-check on 'inclusive energy' sample yields $R_b \approx (92 \pm 3)\% \times R_j$ (note: this is only a preliminary estimate!)
- Several issues to discuss
  - b-response with different taggers
  - combining with semileptonic corrections
  - provide c-response
- DØ will also look into $Z^0 \to b\bar{b}$