Photon-Jet Balance Study: An Alternative

Contributions to Jet Energy Scale Session
in Hadronic Calibration Workshop 2009

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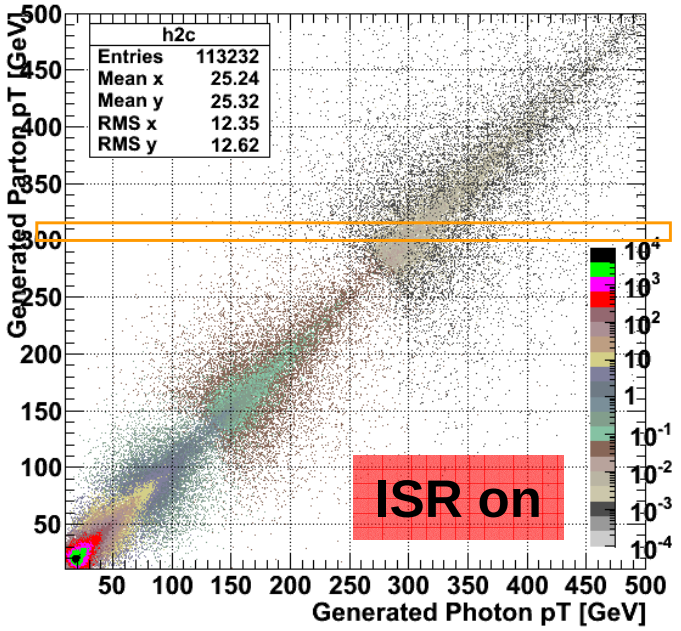
Thanks to
G. Adam and P.O. DeViveiros (Toronto)

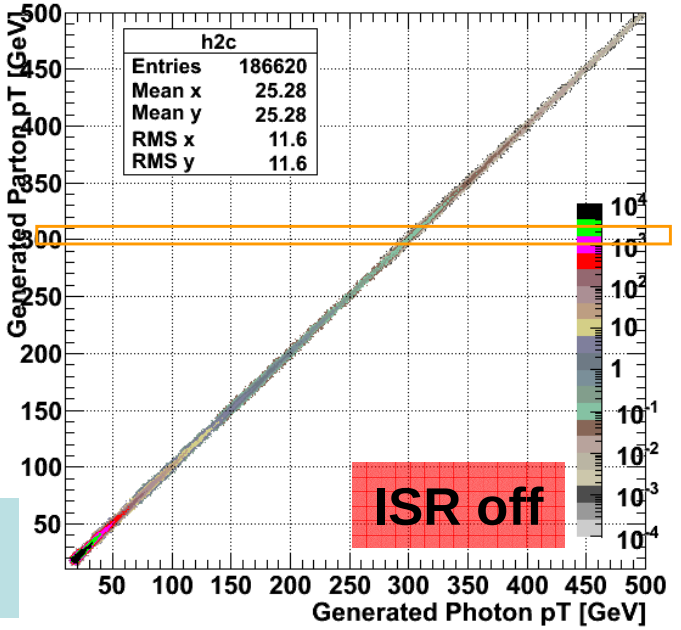
Introduction

- Our goal is to develop in-situ JES calibrations for early data
  - We want to minimize the use of MC and maximize the use of data-driven techniques
- Calibration procedures that make use of MC corrections should also be pursued but it is not what we aim to do here

p_T Balance at Gen. Level (1)

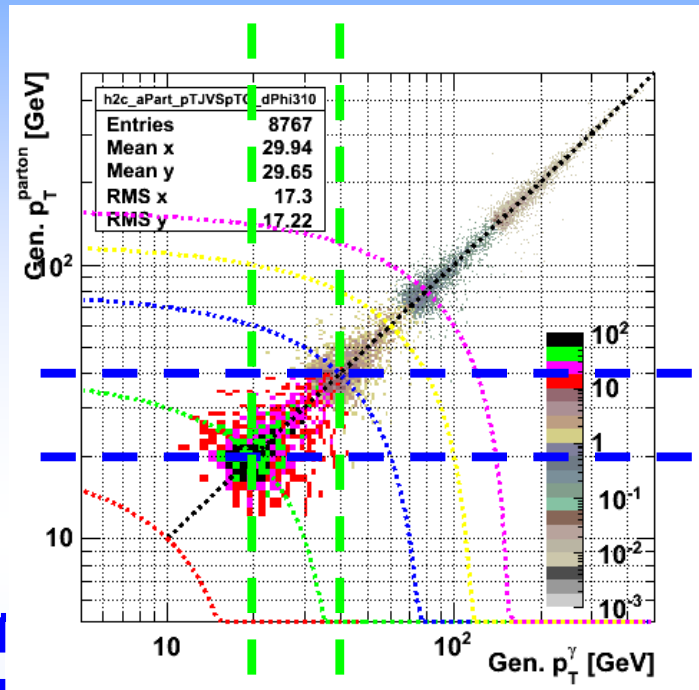
- What can we learn about the Photon-Jet p_T balance at generator level?
  - The outgoing photon DOES NOT balance with the outgoing parton on an event-by-event basis
  - So: we should not correct the reconstructed jet p_T so that it balances the photon p_T
- Why do they not balance?
  - If we compare the p_T balance with ISR switched on and off (shown in the top and bottom plots respectively), we recover most of the one-to-one correspondence between the photon and the parton p_T. So: ISR is the main reason
- Can we correct for this?
  - Yes, we could apply MC-based corrections and would need to figure out corresponding systematics (should be pursued)
  - Yes, by finding a variable that is less sensitive to effects of ISR (this is what we try to do)

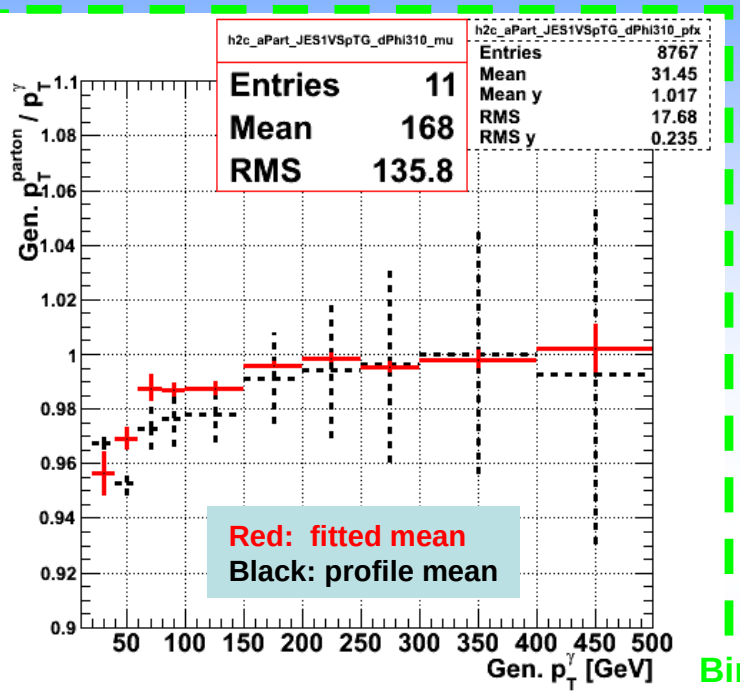




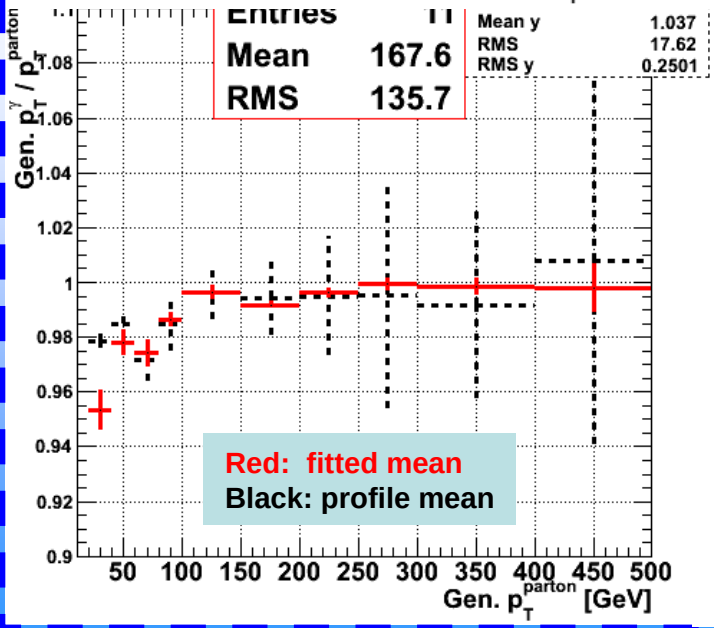
Event generated by standalone Pythia
Selection: dPhi(γ,parton) > 3.1

p_T Balance at Gen. Level (2)





Binned in photon p_T

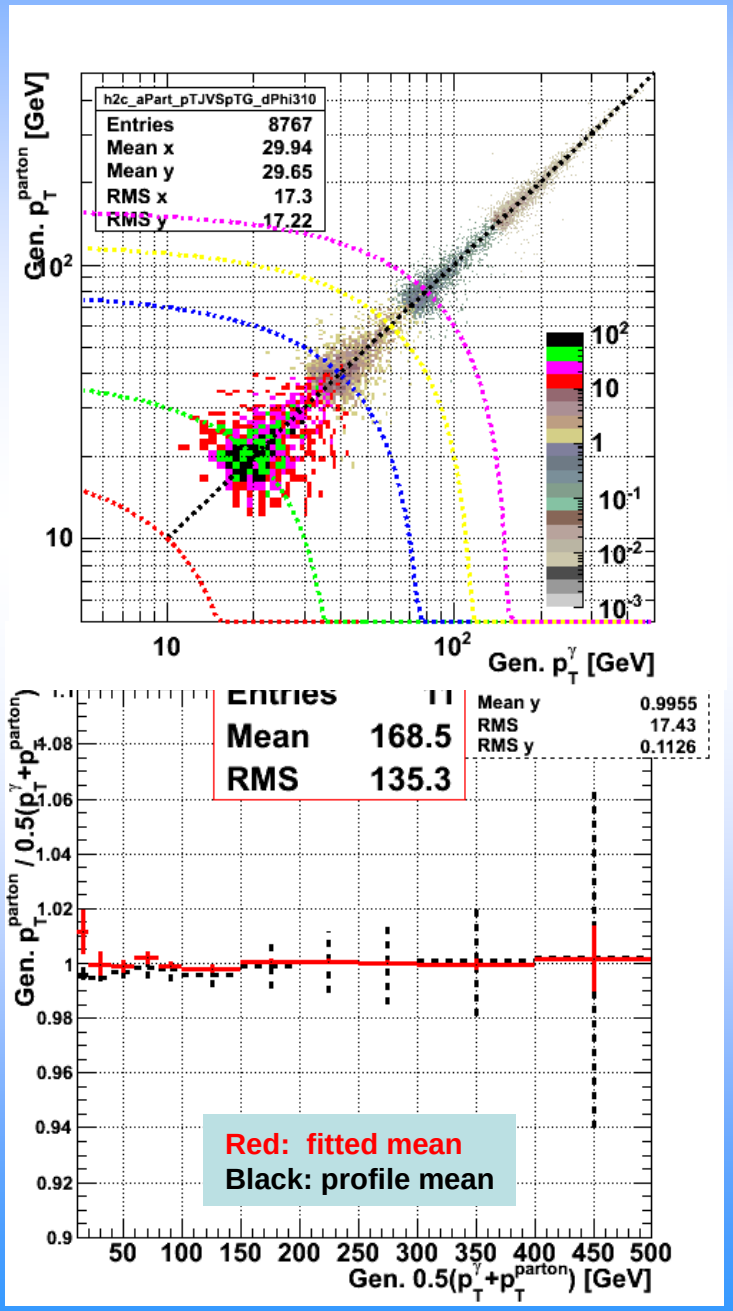


Binned in parton p_T

Red lines: the means and the errors from the Gaussian fit of width 2 sigma

Dashed black: profile plots in gamma or jet pT bins, with the errors for 10pb^{-1} data

p_T Balance at Gen. Level (3)



- Can we find a variable that is less sensitive to ISR?
  - We can bin the events along the diagonal (between green and blue dashed lines): the distribution is symmetric along the diagonal, due to isotropic ISR boost
- We construct a quantity to take into account this symmetry feature:
  - Bottom-left shows p_T balance $p_T^{parton}/0.5(p_T^{\gamma} + p_T^{parton})$ vs $0.5(p_T^{\gamma} + p_T^{parton})$
- Now we have a quantity that should balance at generator level but correction procedure will be more complicated than if we had used parton pT on the x-axis (but which does not balance at generator level…)

This variable has been described in previous notes (ATL-PHYS-PUB-2009-015, Martina Hurwitz ATL-PHYS-INT-2009-014)

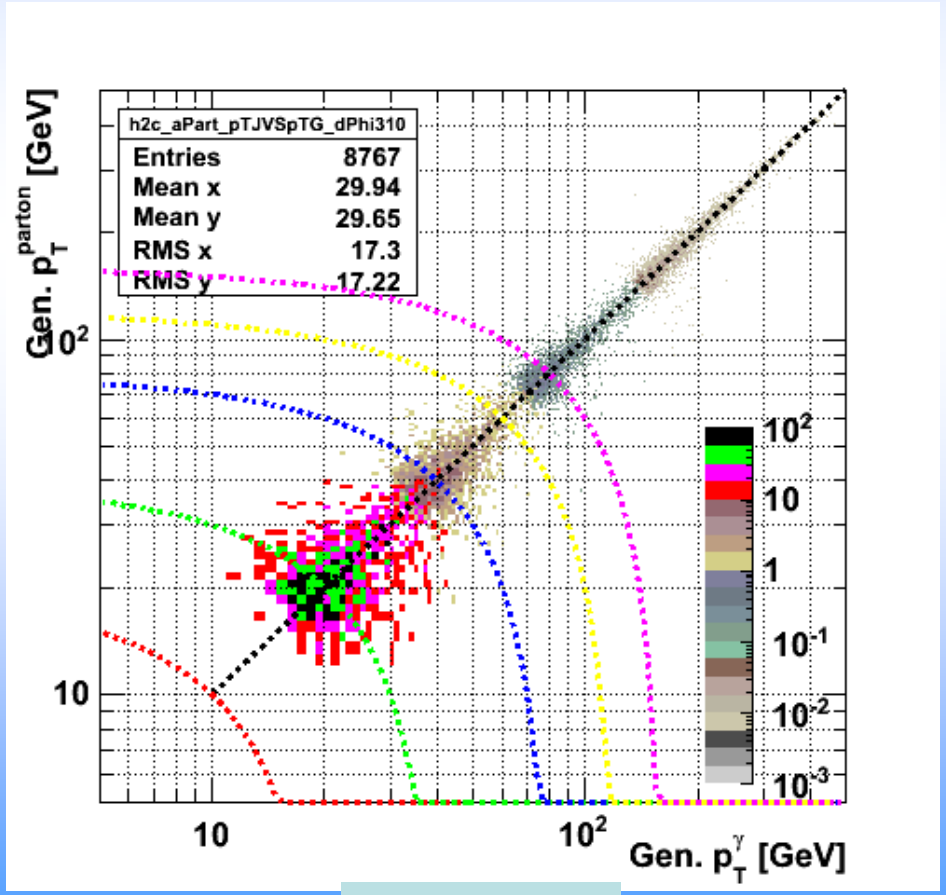
p_T Balance at Reco. Level (1)

- As a first step, we restrict ourselves to a photon-jet topology as much as possible. We used the following stringent cuts (we will relax those cuts later):
  - Good photon isolation: is_em(Tight)=0 + etcone20/p_T<5%
  - The photon and the leading jet back-to-back in ϕ: $\Delta\phi(\gamma,\text{Jet1})>3.1$
  - Reduce radiation effect: 2nd jet p_T<5GeV
  - We only take the events with the leading jet $\eta<=1.0$
  - To compare the reco.-level and corresponding gen.-level quantities, we match the gen. γ and parton to the reco.-level γ and jet
    - dR(parton,Jet1)<0.2 + dR(γ,γ_{gen})<0.1
- H1-calibrated Cone4Tower jets will be taken for an illustration
  - EM-scaled Cone4Tower jets at the backup
- Dataset: 10800X.PythiaPhotonJetX.recon.XXX.e344_s456_r545

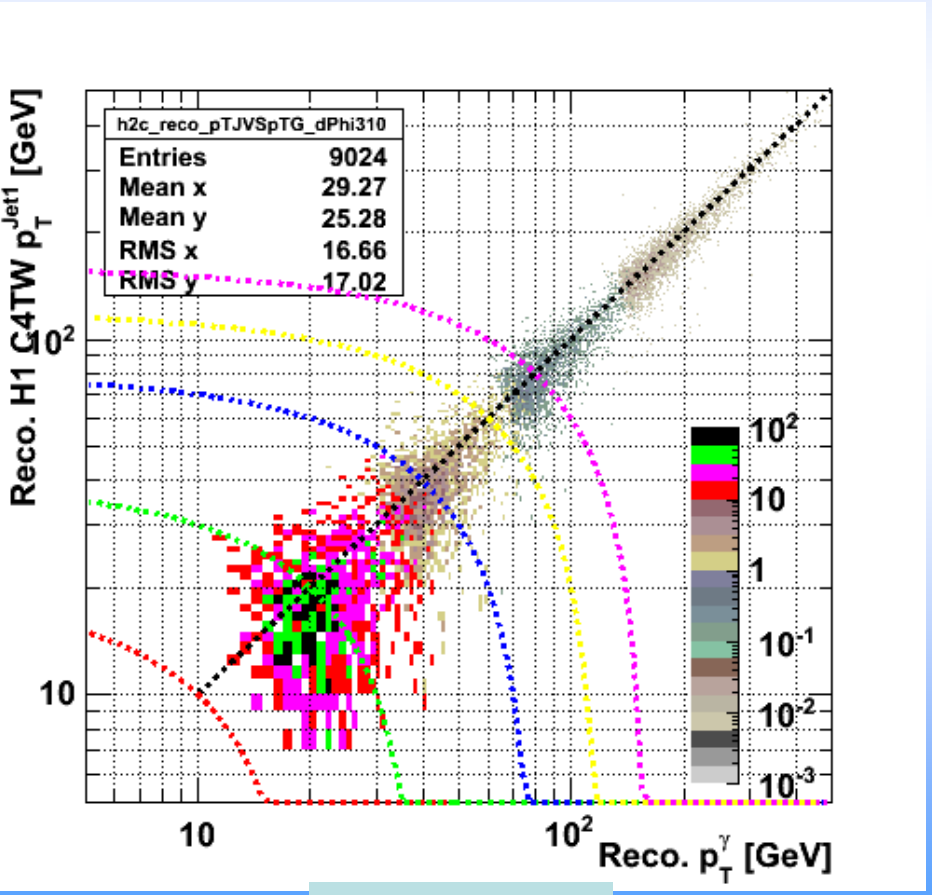
p_T Balance at Reco. Level (2)

We show the 2D distribution of the leading jet p_T^{Jet1} and the photon p_T^{γ} at the generation level on left and the reconstruction level on right

- The event underneath (above) the diagonal means p_T^{Jet1} <(>) p_T^{γ}



Gen. level

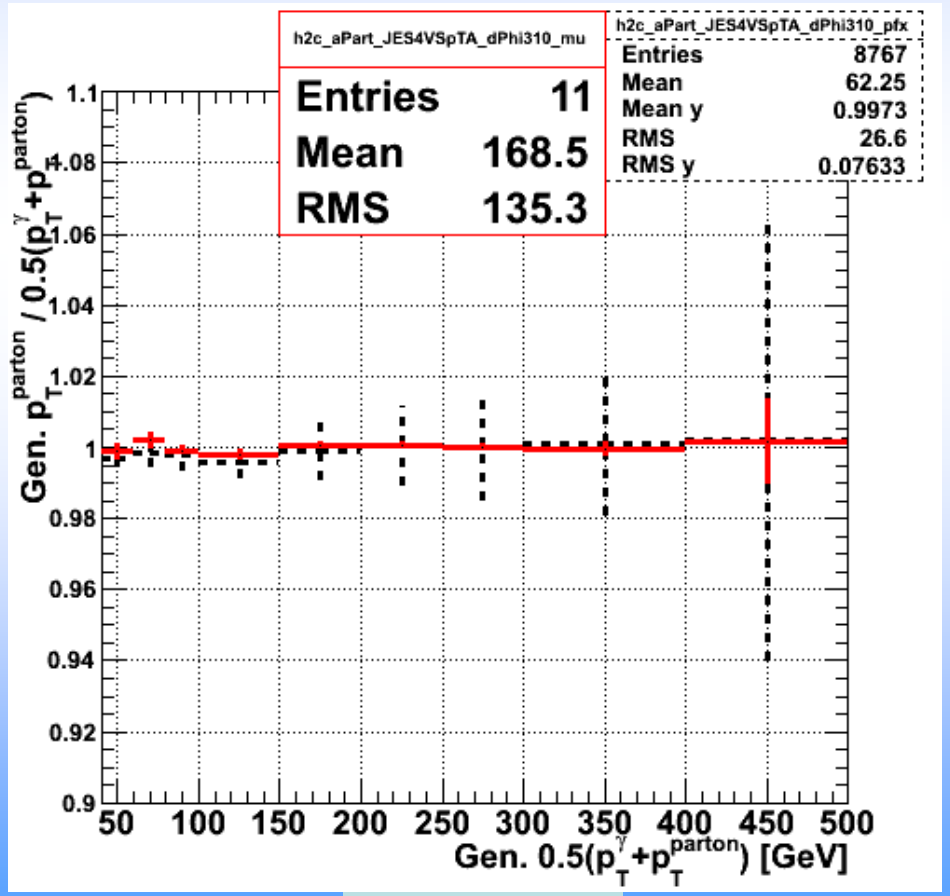


Reco. level

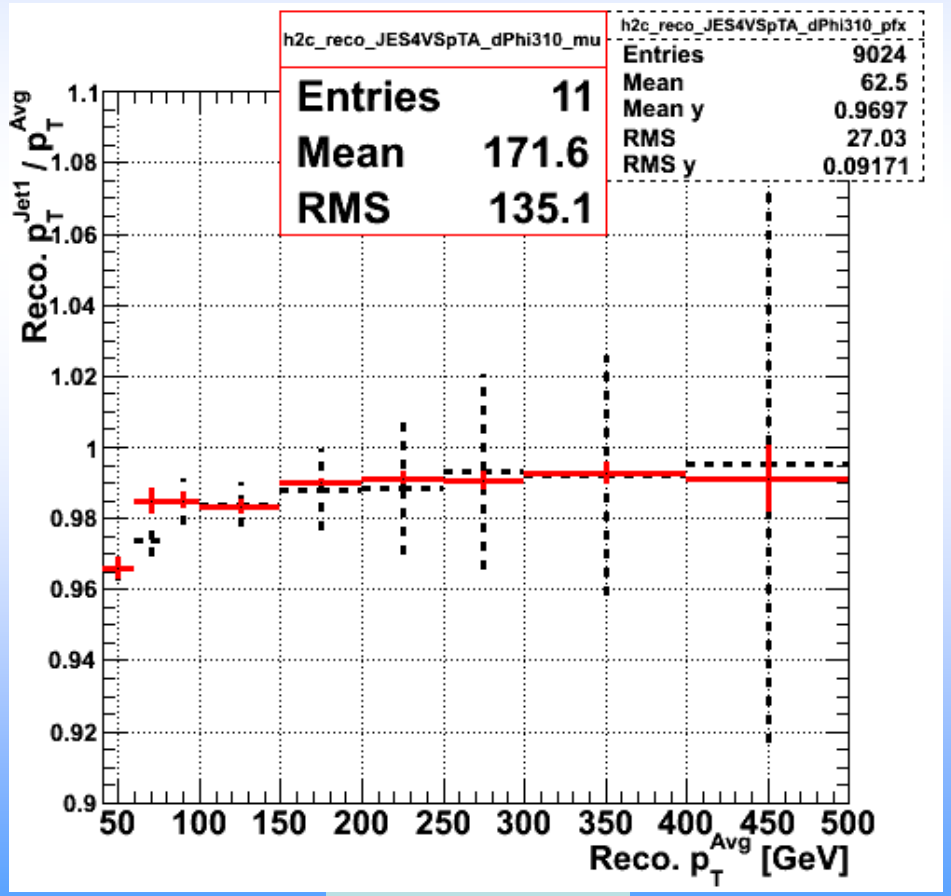
p_T Balance at Reco. Level (3)

We show the diagnostic plot of the previous 2D distribution along the diagonal, i.e., p_T^{Jet1}/p_T^{Avg} vs p_T^{Avg}, with $p_T^{Avg} = 0.5(p_T^{Jet1}+p_T^{\gamma})$

- The reco values are below 1: p_T^{Jet1} is under-calibrated in the hadronic Cone4Tower case



Gen. level

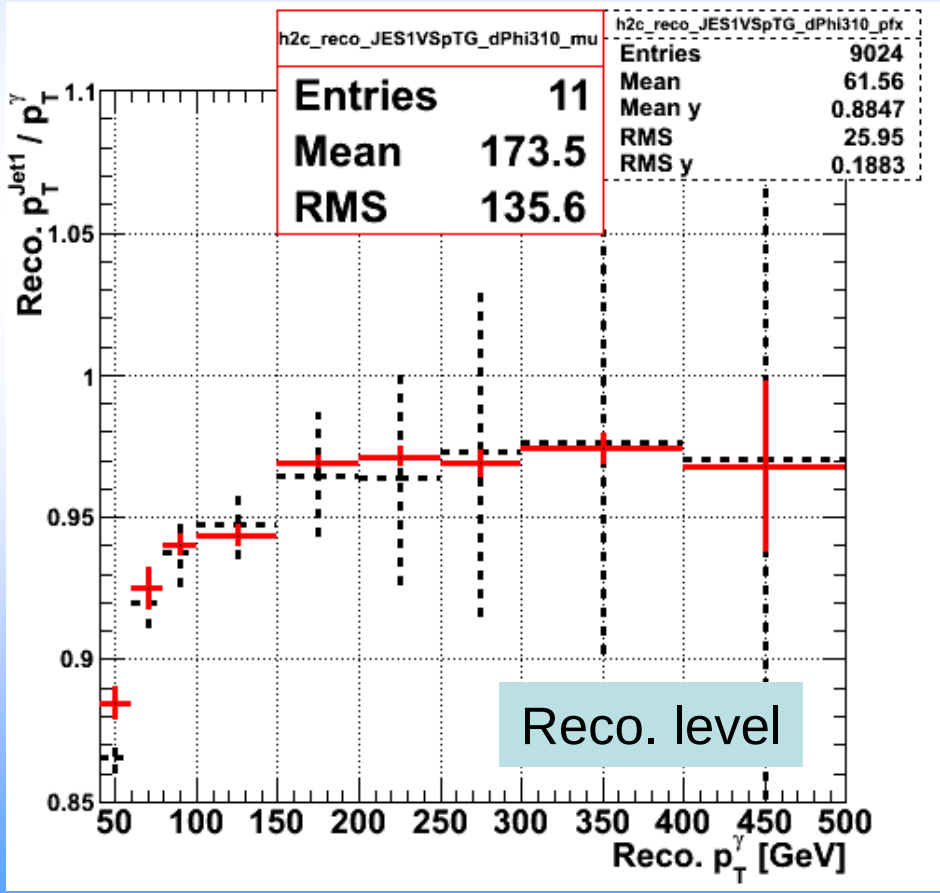


Reco. level

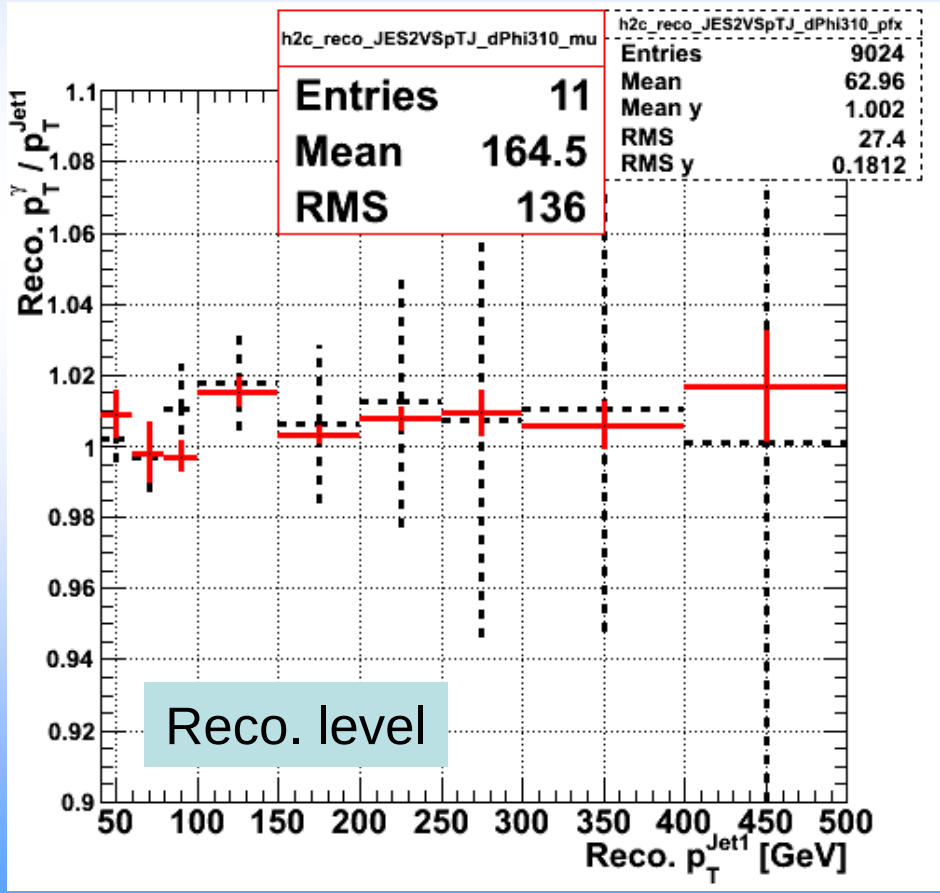
p_T Balance at Reco. Level (4)

If you wonder what the p_T balance looks like on either photon or Jet1 p_T binning …

This plot tells you jets are under-calibrated by a lot…



This plot tells you a different story…



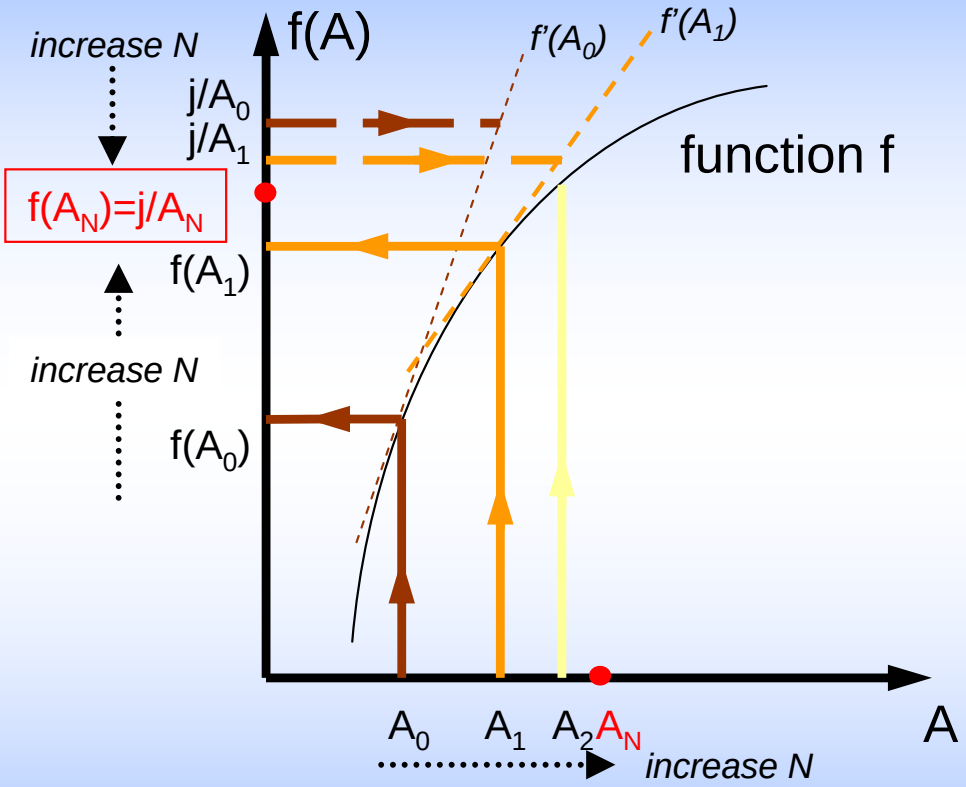
(The corresponding generator-level plots are shown in previous pages)

Extracting the Correction Factor (1)

- If we used the p_T of the uncorrected jet on the x axis, the correction factor would be trivial to extract
- Since we use p_T^{Avg} on the x axis, the extraction of the correction factor requires a little bit of math: we chose the iteration procedure described below (essentially Netwon's method):

Let's say we can describe this p_T balance by a simple function f

1) To start with, assume the corrected p_T^{Jet1} $p_T^{\gamma 0} = \gamma_0 = j$ = uncorrected p_T^{Jet1}
2) In 0^{th} iteration, A_0 is calculated and $f(A_0)$ is found from function f
3) Draw a tangent $f'(A_0)$ to f at A_0
4) Calculate A_1 from the tangent given j/A_0
5) A_1 is found from the tangent and thus γ_1
6) Go back step 2) for next iteration till the difference between successive iterations is less than the tolerance

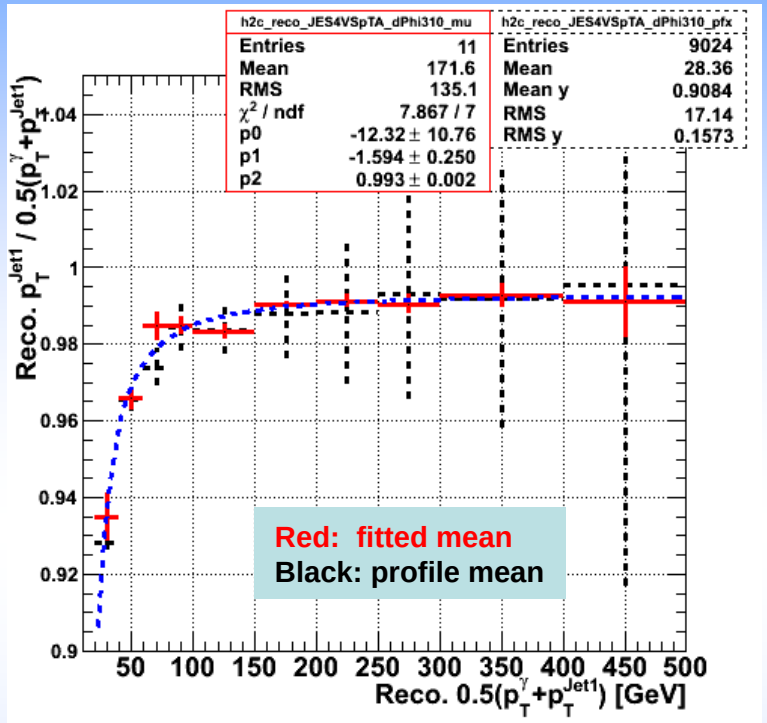


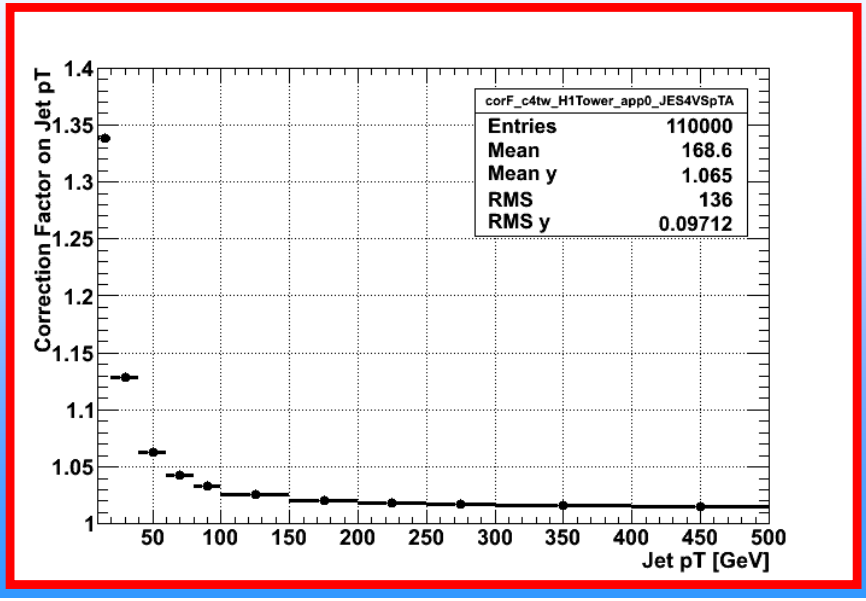
0^{th} iter: Input: γ_0 ➔ $A_0=0.5(\gamma_0+j)$ ➔ Output: γ_1
1^{st} iter: Input: γ_1 ➔ $A_1=0.5(\gamma_1+j)$ ➔ Output: γ_2
2^{nd} iter: Input: γ_2 ➔ $A_2=0.5(\gamma_2+j)$ ➔ Output: γ_3
N^{th} iter: γ_N

Extracting the Correction Factor (2)

- Given the iteration procedure, we fit the p_T balance curve by a simple exponential shown on the top

- Given an uncorrected jet p_T, we can go through the procedure and find the correction factor
  - We will take this correction (in red frame) for the closure tests and validation tests for the following

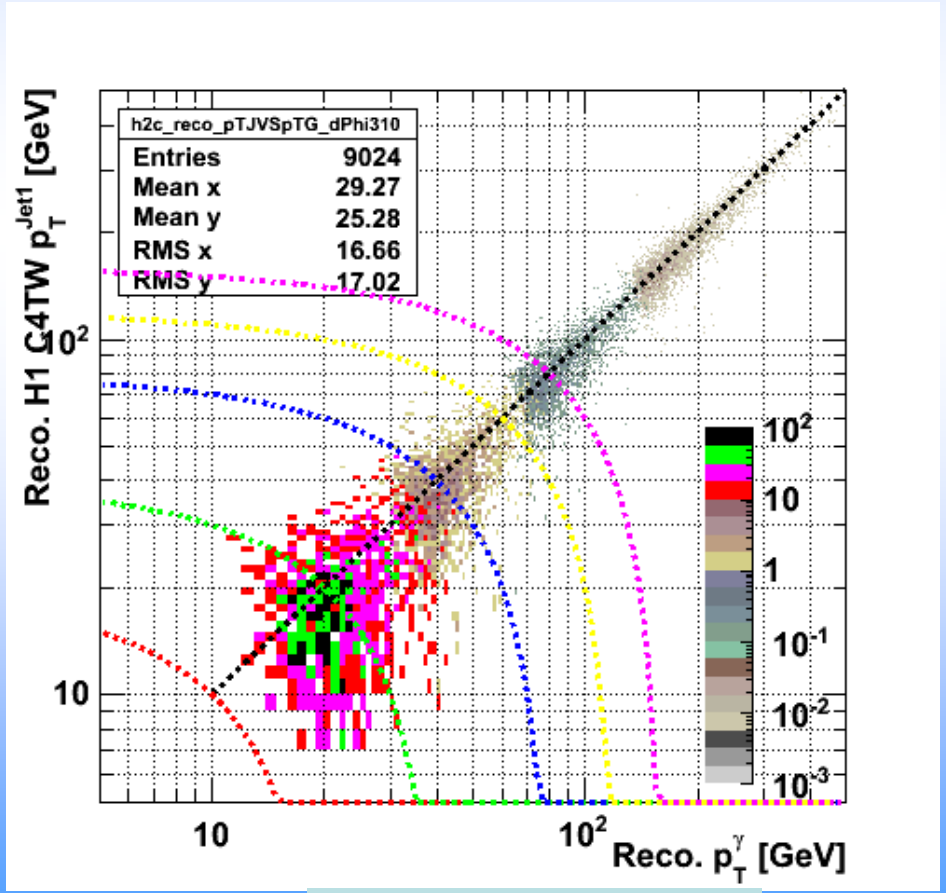




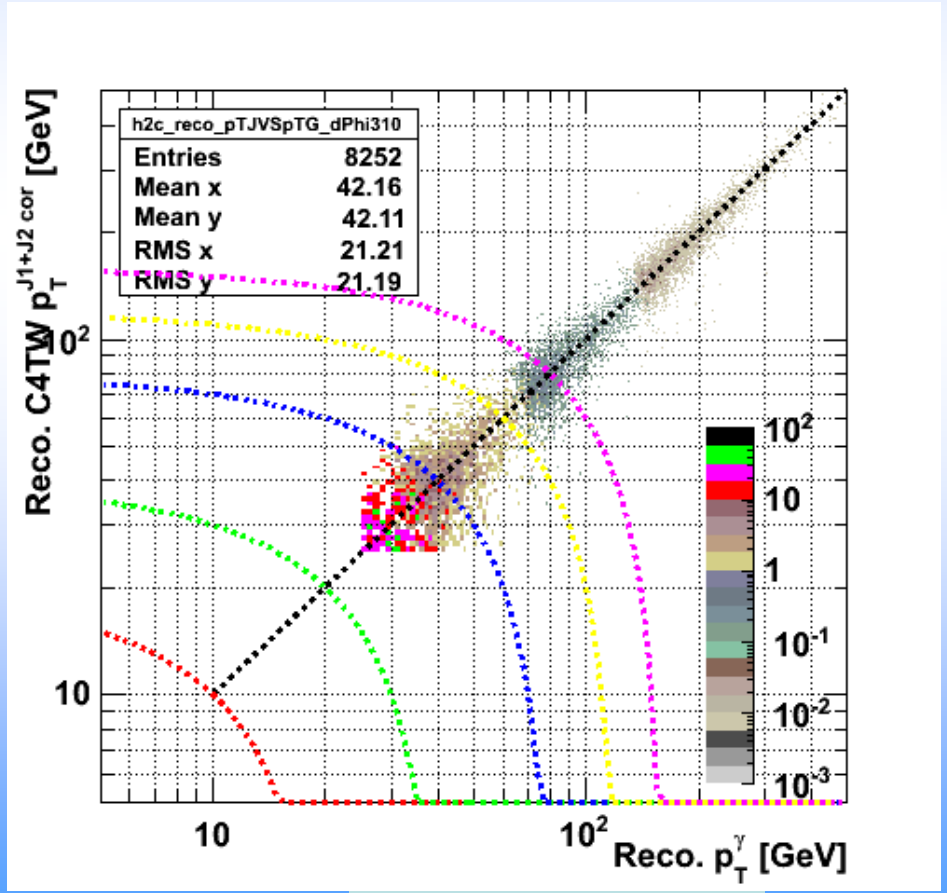
Closure Test at Reco. Level (1)

We show again the 2D plots before (on left) and after (on right) the correction

- To avoid generator/reconstruction biases, we add extra cuts after the correction
  - p_T^{γ} , $p_T^{\text{Jet1 cor}} > 25\text{GeV}$



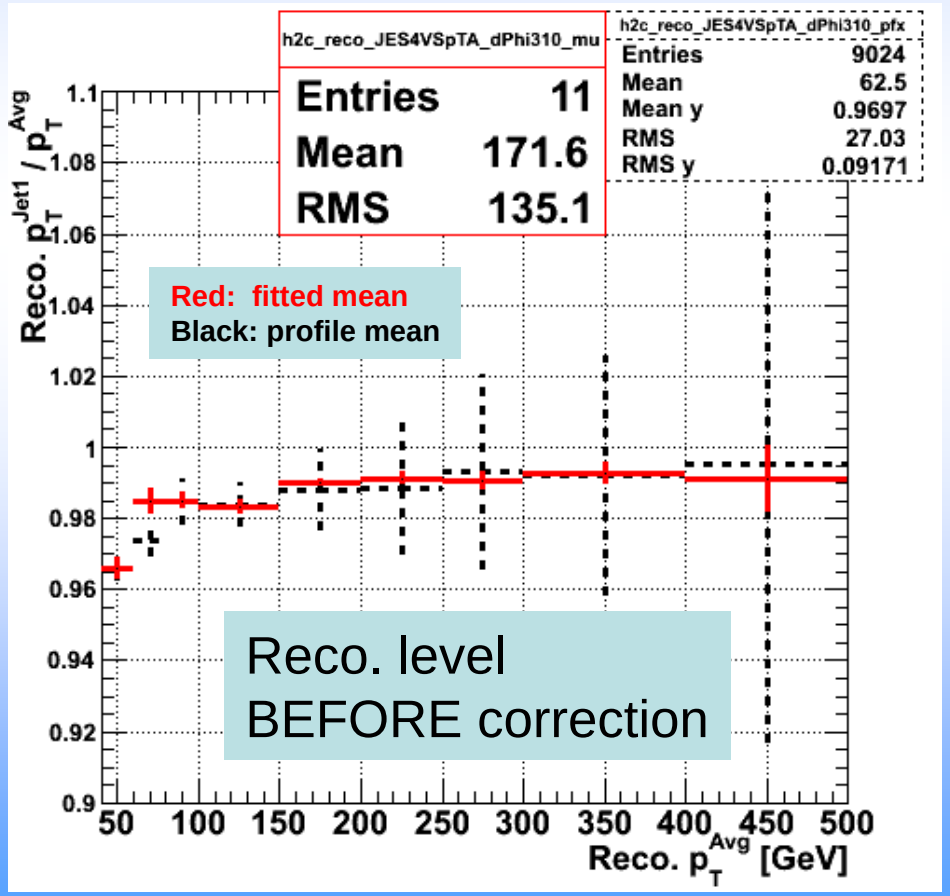
Reco. level
BEFORE correction

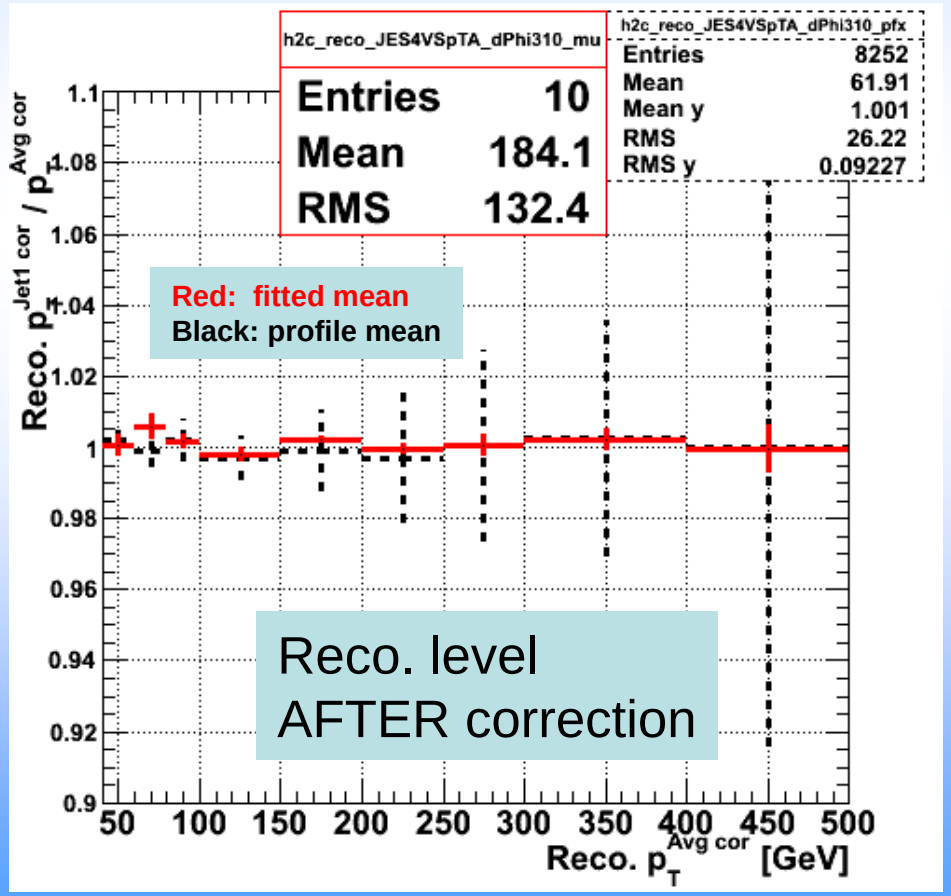


Reco. level
AFTER correction

Closure Test at Reco. Level (2)

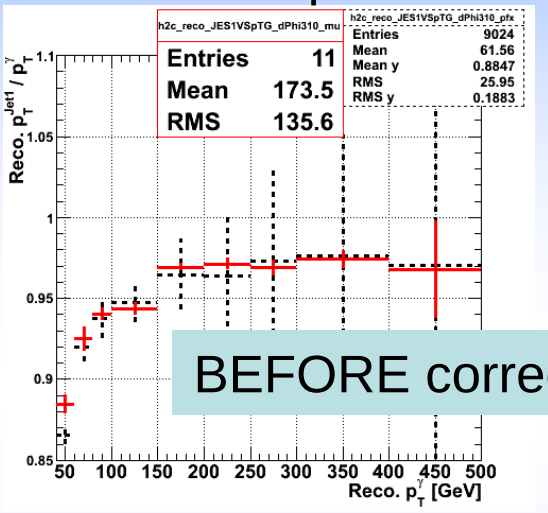
- The p_T balance is flat after applying the correction





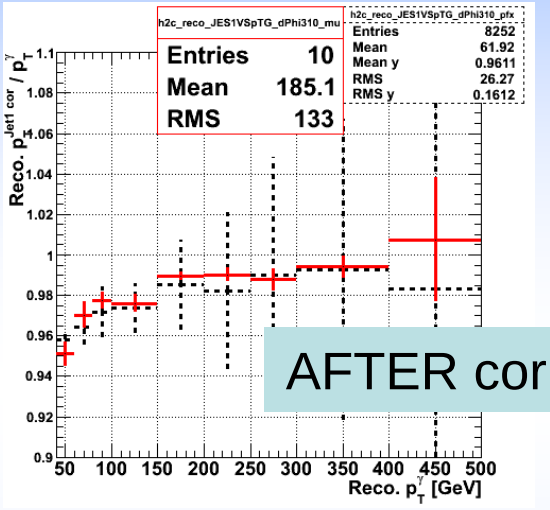
Closure Test at Reco. Level (3)

If you wonder again what the p_T balances look like BEFORE AND AFTER the correction on either photon or Jet1 p_T binning …

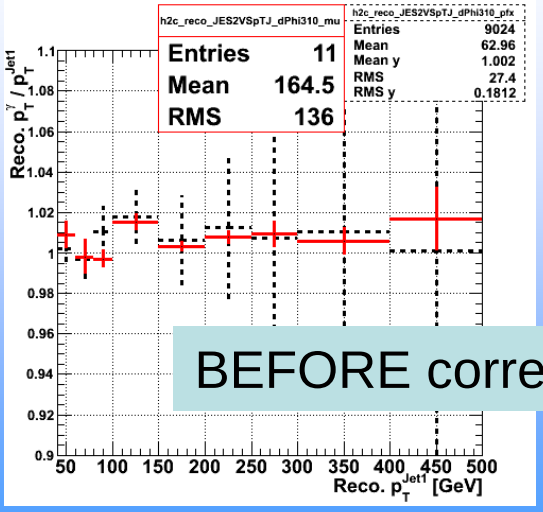


BEFORE correction

Red: fitted mean
Black: profile mean

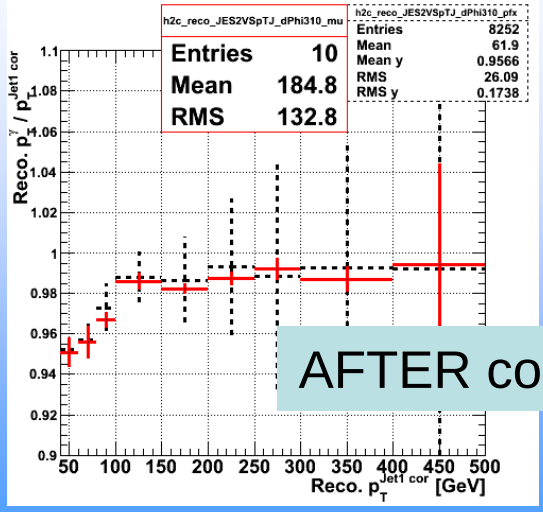


AFTER correction



BEFORE correction

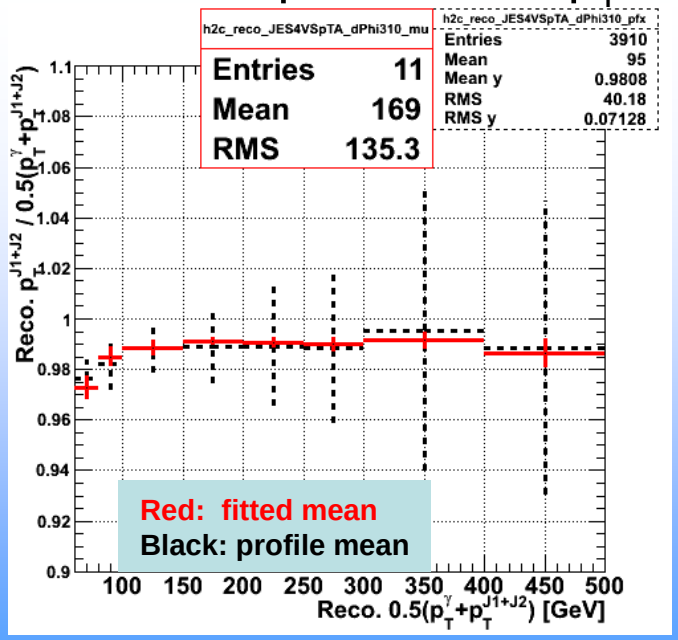
Red: fitted mean
Black: profile mean



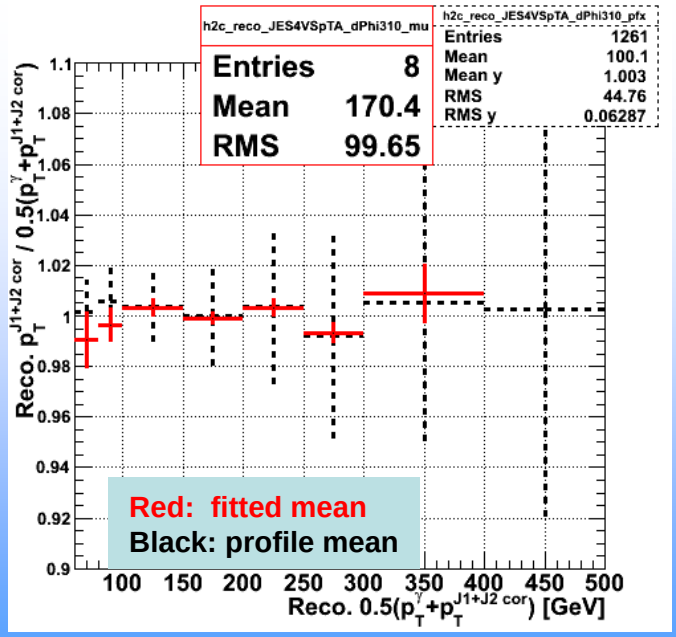
AFTER correction

Validation Test

- The events with 1 photon+2 jets correspond to a different population than the events that were used to derive the correction: we use this sample to validate the procedure
- For this test, we apply the following selections and cuts
  - Apply the same selection as to the population of 1 photon+1 jet
  - Correct first these 2 jets individually, followed by $p_T^{\text{Jetx cor}} > 25\text{GeV}$
  - Merge them together to form a single jet and $p_T^{\text{J1+J2 cor}} > 50\text{GeV}$ (same as to photon, i.e., $p_T^{\gamma} > 50\text{GeV}$)



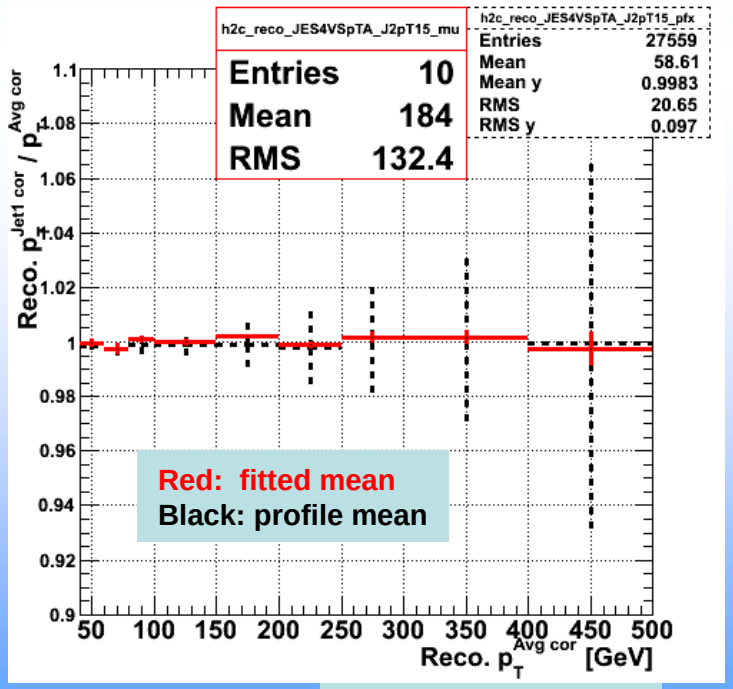
BEFORE correction



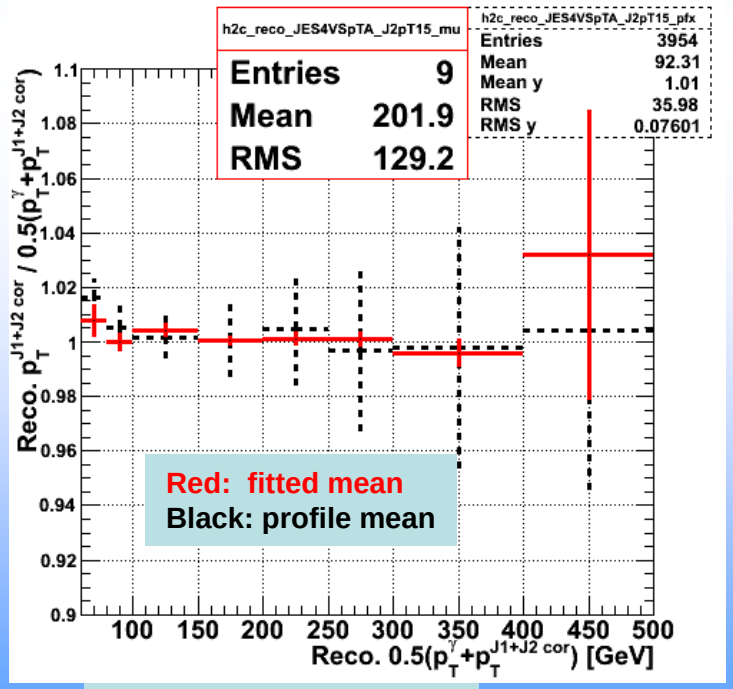
AFTER correction

Relaxing the Selection Cuts

- If p_T^{Avg} is robust against ISR, we should be able to relax our cuts and increase our photon+jet statistics significantly
- For the plots below we used 2nd jet p_T < 15 GeV and $\Delta\phi > 2.9$. This increases our statistics by a factor ~ 3 at p_T bin [150,200]GeV. Other plots with increased jet p_T threshold are in backup slides (increases stats by factor of ~6)



Closure Test



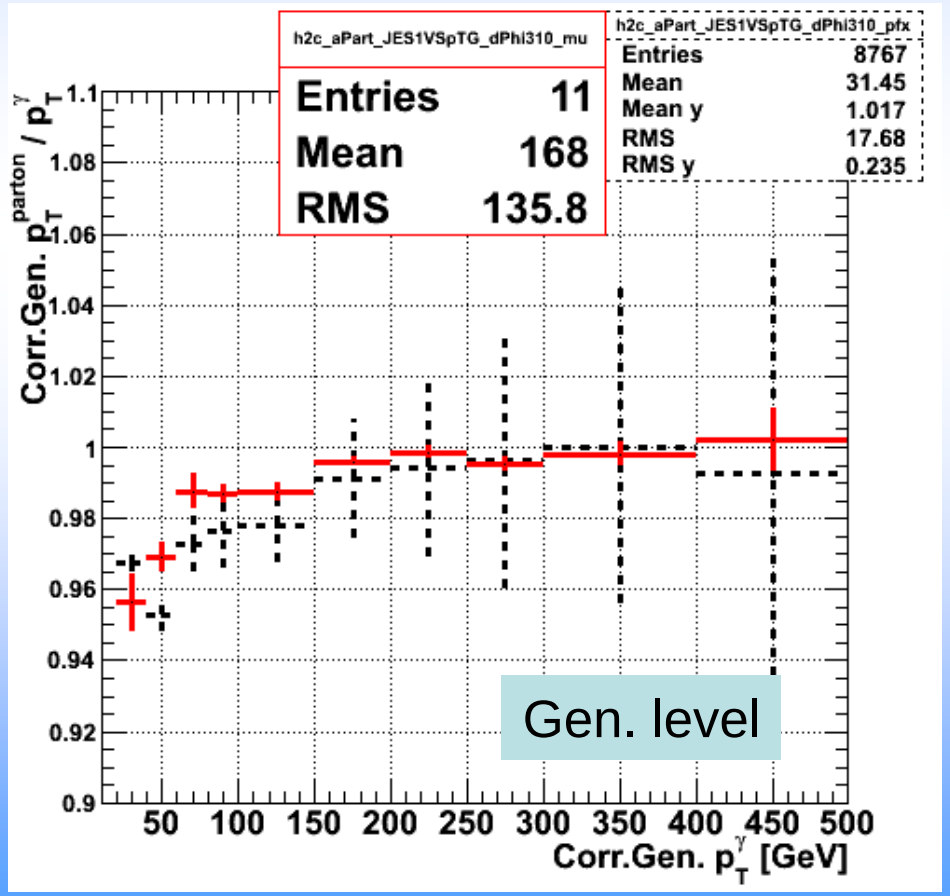
Va;idation Test

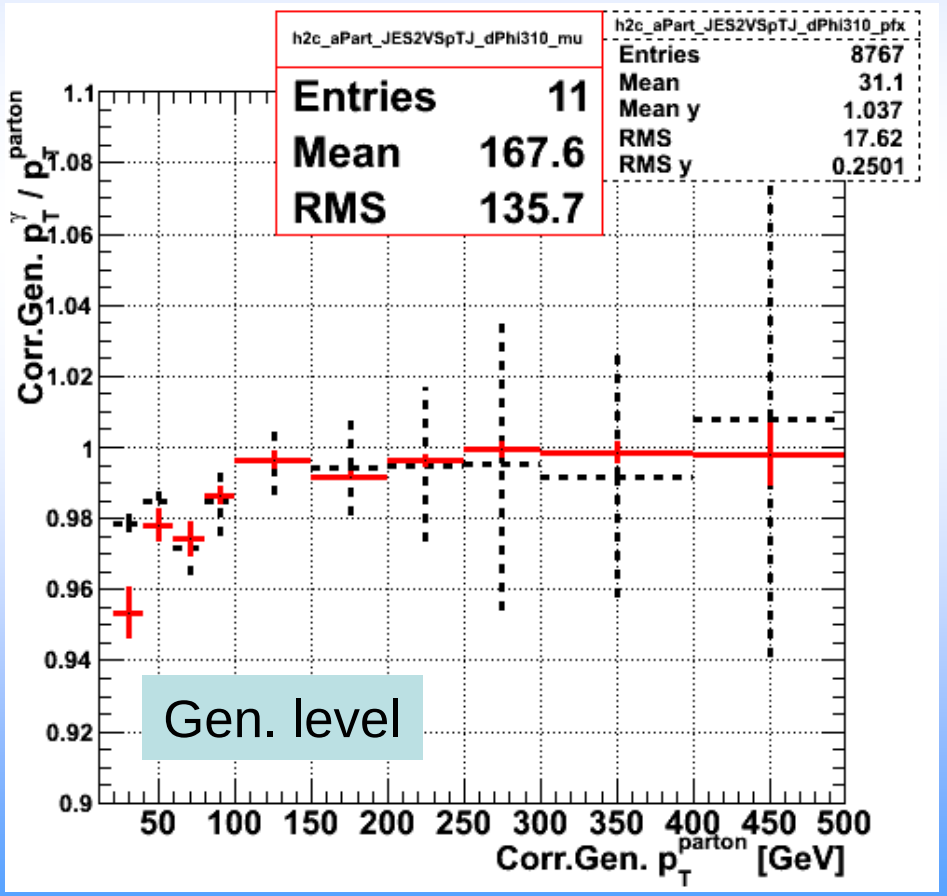
Conclusion

- In photon-jet events, we do not expect the gamma p_T and the jet p_T to balance on an event-by-event basis
  - ISR seems to be the main reason for this imbalance
  - We can use a different variable on the x-axis that will be less sensitive to ISR (mentioned in previous ALTAS notes – see M. Hurwitz)
- We developed an iteration method to extract jet energy corrections
  - We tested the method's self-consistency with our "closure test" and showed that it worked on events not used for extracting the corrections i.e. the "validation test"
- Things to do:
  - Continue to study looser selection cuts
  - Add W mass reconstruction validation test (although quarks from colour singlet are not expected to reconstruct at the exact mass if correction is derived from "generic jets"…)
  - Add low-mass excited quark resonance sample (with mass few tens to hundreds GeV) for fair validation

Backup

Correspondence to p_T Balance at Reco. Level (4)

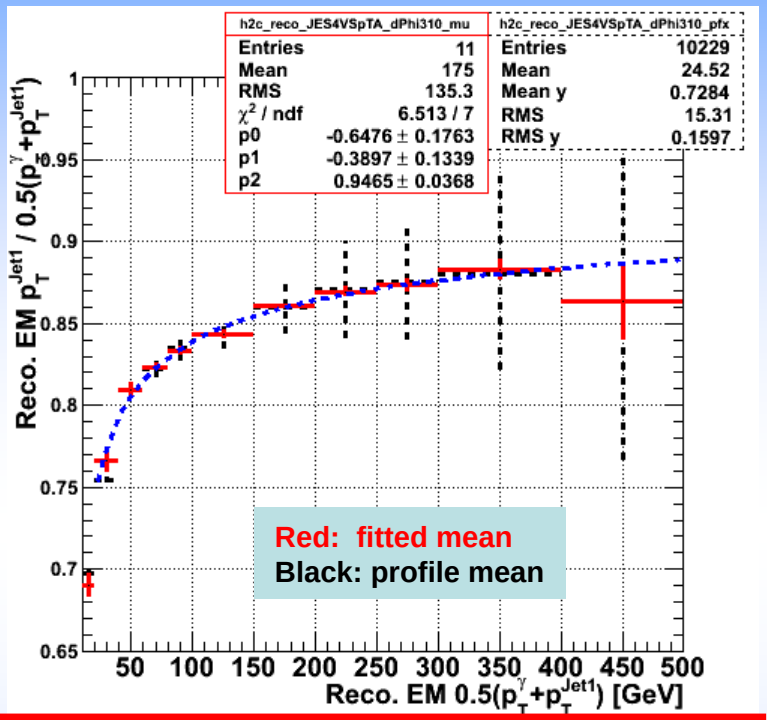


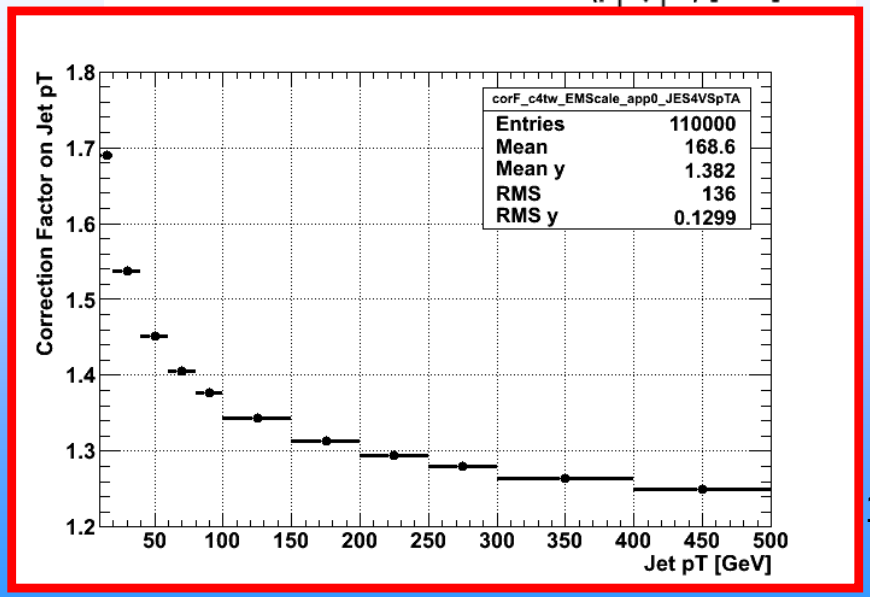


How to Get EMS Correction Factor?

- Given the iteration procedure, we fit the p_T balance curve by a simple exponential shown on the top

- Given an uncorrected jet p_T, we can go through the procedure and find the corrected jet p_T (which is p_T^{γ}) shown at the bottom
  - We havent included the errors from the fit, but in principle it's doable
  - We will take the correction plot (red-framed) for the closure tests and validation tests in the following

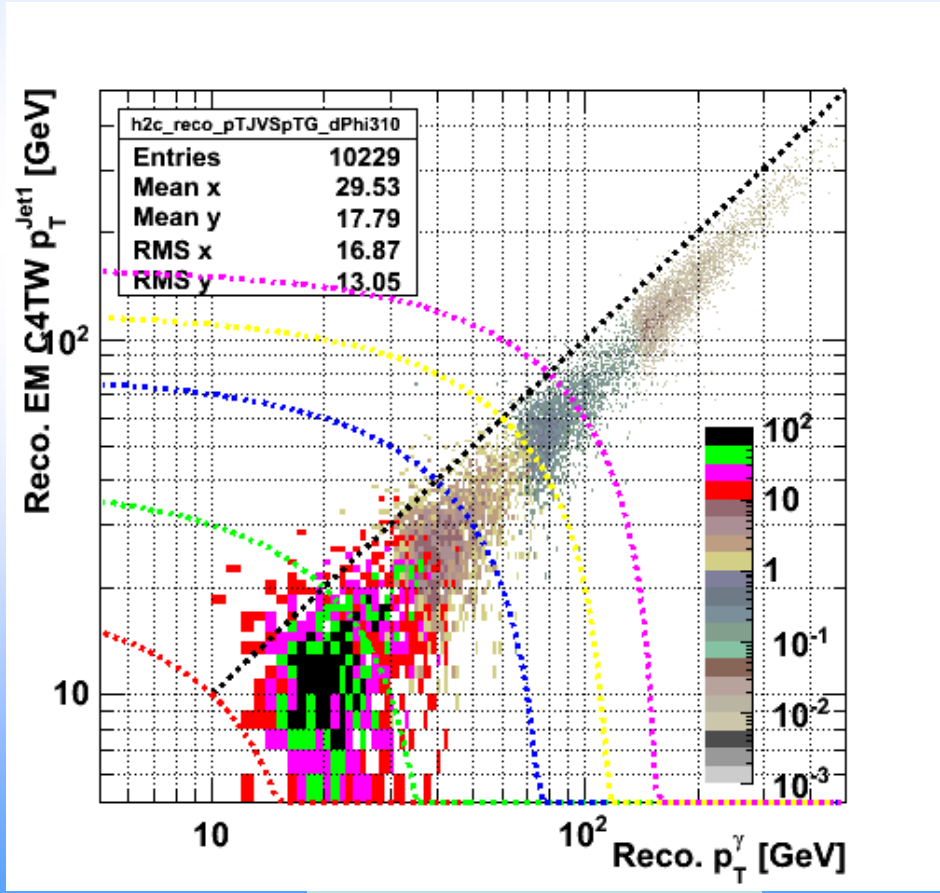




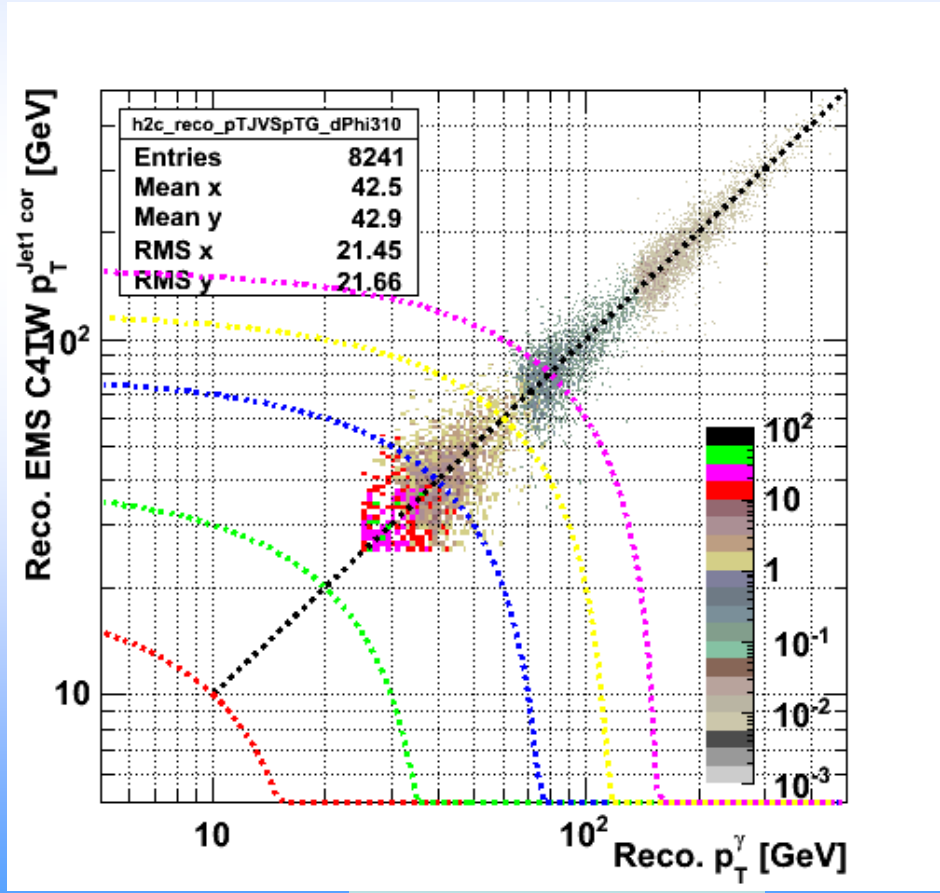
Closure Test at EMS Reco. Level (1)

We show again the 2D plots before (on left) and after (on right) the correction

- Since we only interest in high pT region, we add extra cuts after the correction
  - p_T^{γ} , $p_T^{\text{Jet1 cor}} > 25\text{GeV}$



Reco. level
BEFORE correction

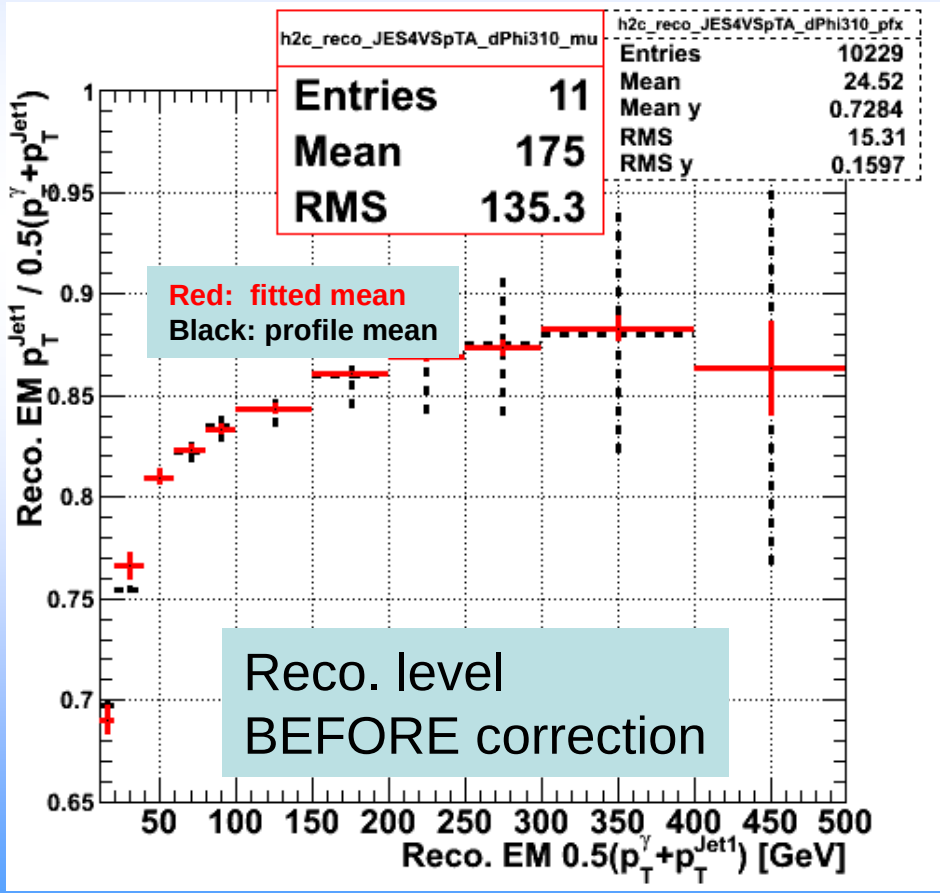


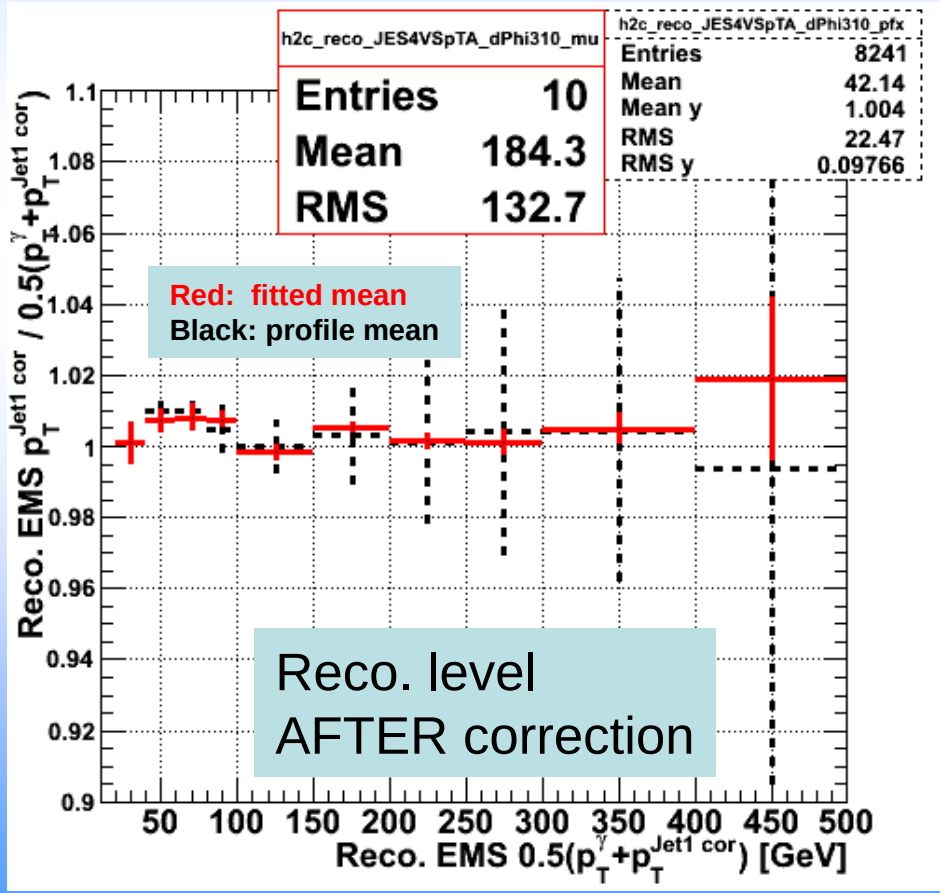
Reco. level
AFTER correction

Closure Test at EMS Reco. Level (2)

How about the diagnostic plots?

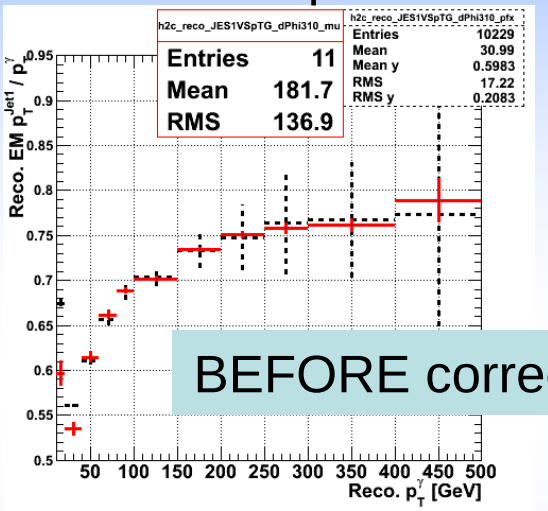
- The pT balance quantity is flatten after applying the correction





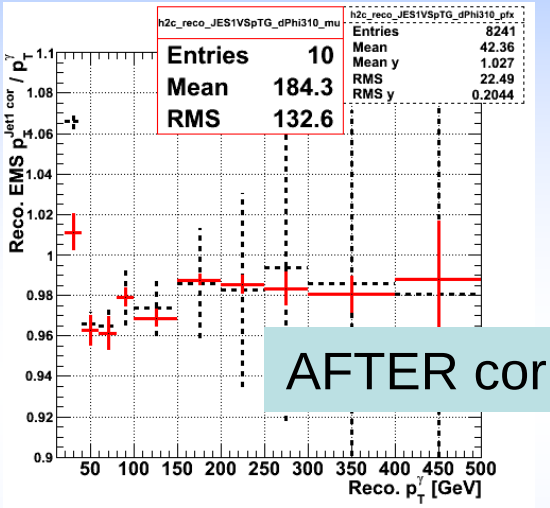
Closure Test at EMS Reco. Level (3)

If you wonder again what the p_T balances look like BEFORE AND AFTER the correction on either photon or Jet1 p_T binning …

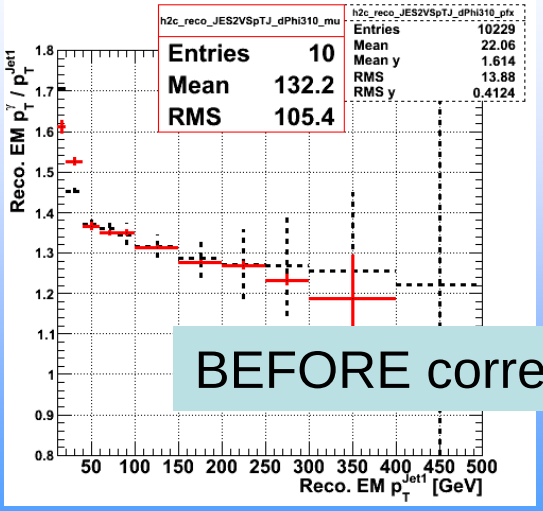


Red: fitted mean
Black: profile mean

BEFORE correction

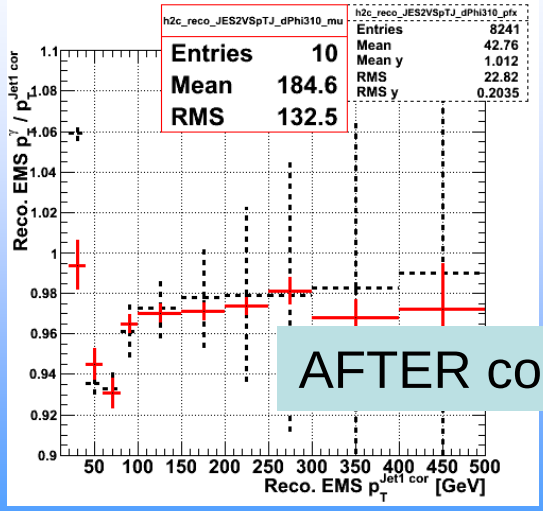


AFTER correction



Red: fitted mean
Black: profile mean

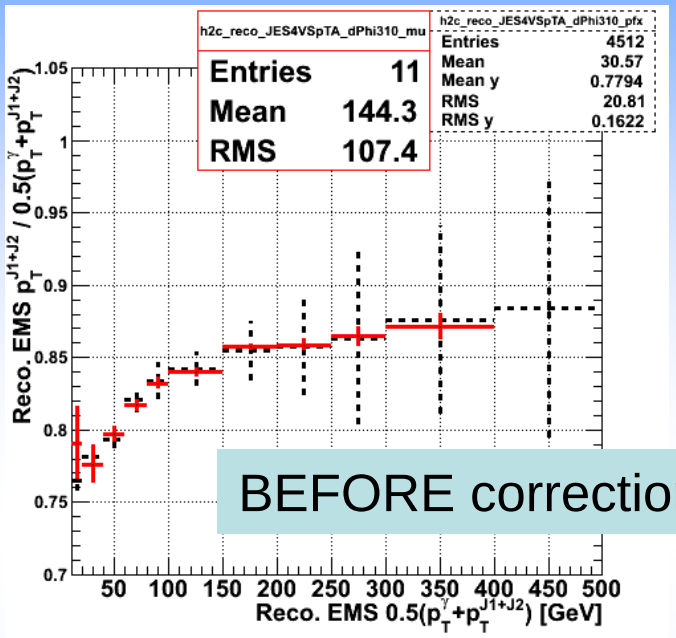
BEFORE correction



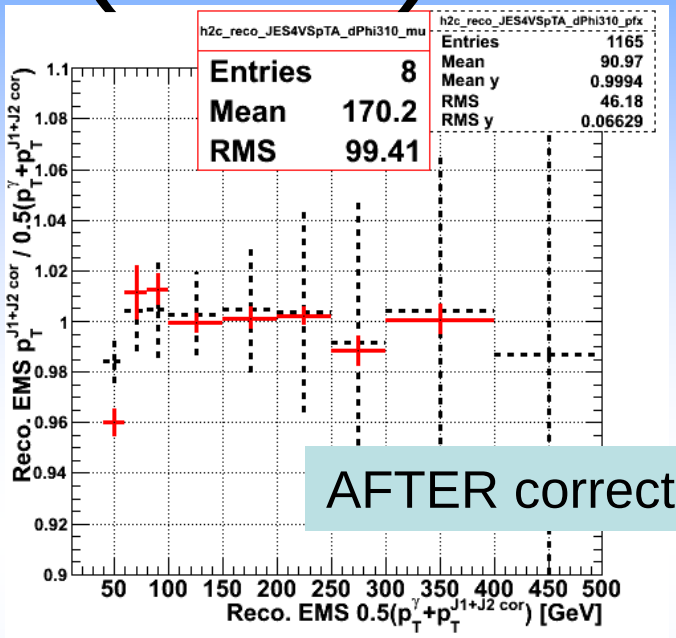
AFTER correction

(The corresponding ones in backup)

Validation Test (EMS)



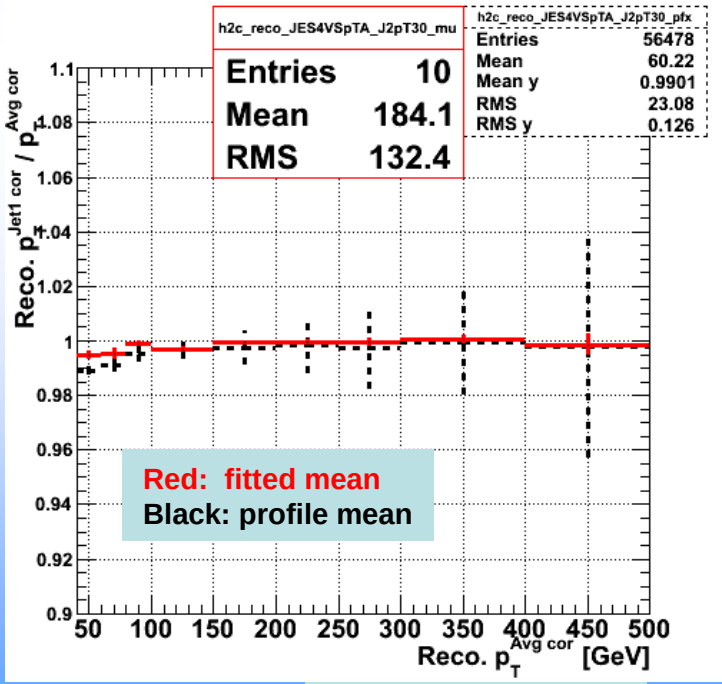
Red: fitted mean
Black: profile mean



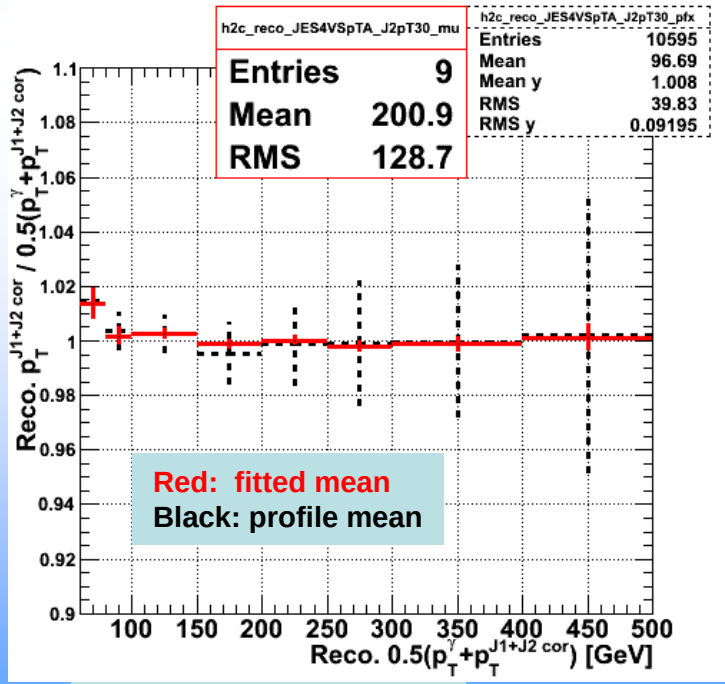
- The events with 1 photon+2 jet are taken for the validation
  - This is different population to the one that the correction factor is derived from the same sample
  - Using these events can avoid any inconsistencies among the samples
- In order to carry the same study on 1 photon+2 jet
  - Correct first these 2 jets individually, followed by $p_T^{Jetx\ cor} > 25GeV$
  - Merge them together to form a single jet and $p_T^{J1+J2\ cor} > 50GeV$ (same as to photon, i.e., $p_T^{\gamma} > 50GeV$)
  - Apply the same selection as to the population of 1 photon+1 jet

Relaxing the Selection Cuts

- If p_T^{Avg} is robust against ISR, we should be able to relax our cuts and increase our photon+jet statistics significantly
- For the plots below we used 2nd jet p_T < 30 GeV and $\Delta\phi > 2.9$. This increases our statistics by a factor ~ 6 at p_T bin [150,200]GeV.



Closure Test



Va;idation Test