Use of AMWT in dilepton top charge asymmetry, spin correlation, and polarisation measurements

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Mini-workshop on top decay reconstruction
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Background

- We use unfolded asymmetry distributions to measure top quark properties in the dilepton final state
  - Spin correlation and polarisation
    - http://cms.cern.ch/iCMS/jsp/analysis/admin/analysismanagement.jsp?ancode=TOP-13-003
    - http://arxiv.org/abs/1311.3924
  - Charge asymmetry
    - http://cms.cern.ch/iCMS/jsp/analysis/admin/analysismanagement.jsp?ancode=TOP-12-010

- Most of these measurements require reconstruction of the ttbar system
  - We use the AMWT (arXiv:1105.5661), with some customisations

AMWT (analytical matrix weighting technique)

- In arXiv:1105.5661, AMWT is used to measure m_t
- Dilepton ttbar system is fully constrained for given m_t (assumed the same for both tops)
- m_t is scanned from 100 to 300 GeV
  - two possible lepton-jet combinations and up to 4 neutrino solutions => up to 8 possible solutions per m_t point
  - weight w is assigned to each solution:

$$w = \left\{ \sum F(x_1) F(x_2) \right\} p(E^*_{\ell+} | m_{\mathrm{top}}) p(E^*_{\ell-} | m_{\mathrm{top}})$$

PDFs

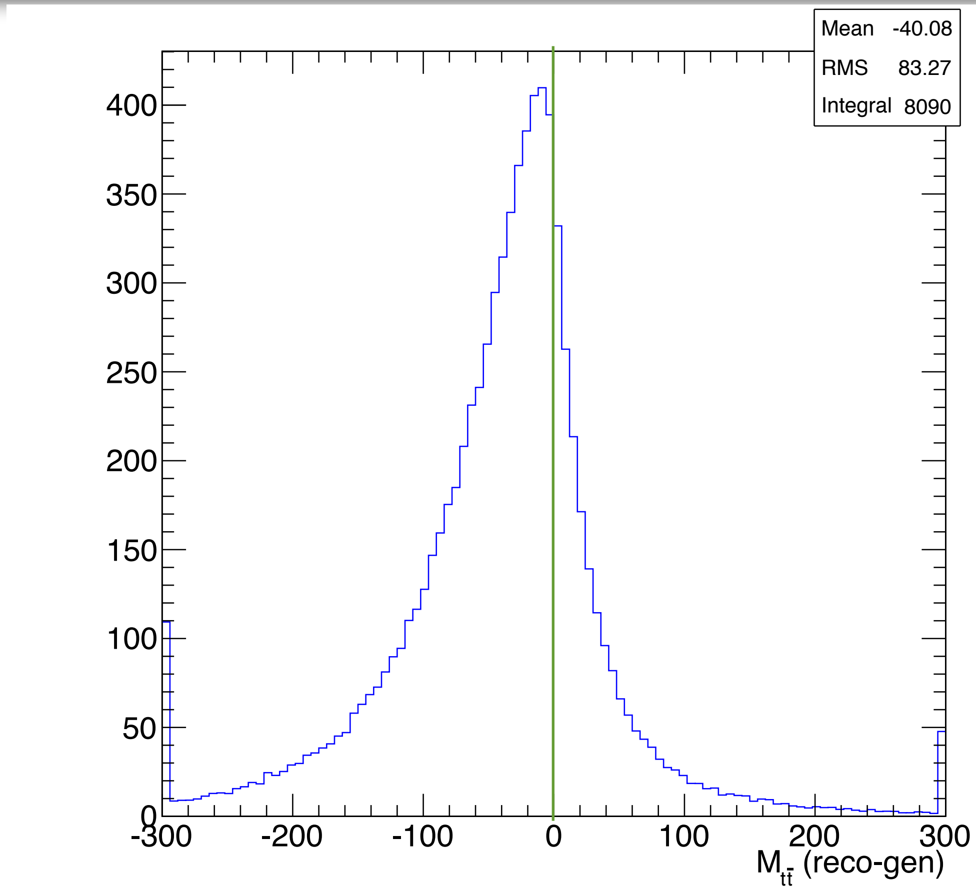
probability lepton has energy E^* in parent top CM

  - preferred m_t indicated by value with largest sum of solution weights
- Sum of weights averaged over 1000 jet smearing iterations
  - random jets thrown based on the known jet measurement resolution, so this is basically a Monte Carlo integration over the jet resolution functions
- m_t taken from the value with largest average sum-of-weights

AMWT to determine tt kinematics

- Instead of finding a preferred value of m_t, we want to use the AMWT to find the most likely ttbar kinematics
  - instead of scanning m_t, can use constraint $m_t = m_t^{measured}$ to improve the resolution of the reconstruction (we used m_t = 172.5 GeV)
- In the absence of jet smearing it's easy to choose the most likely ttbar kinematics
  - of the up to 8 possible solutions, take the one with largest weight, w
- After adding jet smearing, there are very many possible solutions (from 1000 iterations * 8 possible solutions)
- At first we tried taking the ttbar kinematics from the single solution with largest weight among all the jet smearing iterations
  - we found this gives biased results (next slide)

Bias from jet smearing



- Taking the single solution with largest weight is a poor choice because the weight does not disfavour the iterations with large (unlikely) smears
  - result is a bias towards the tails of the jet resolution distributions, that gets worse as the number of iterations is increased
  - we also find that, on average, the AMWT weight increases when the jet p_Ts are reduced (weight not normalised wrt input kinematics?)
    - so the bias is towards the low tail of the jet p_T smearing distribution
    - results in significant bias on reconstructed ttbar system, and variables such as m_{ttbar} (see above, more plots later)
- Note that this problem does not affect the m_t estimate used in arXiv:1105.5661, because this is taken from the average over jet smearing iterations

Jet smearing with no bias

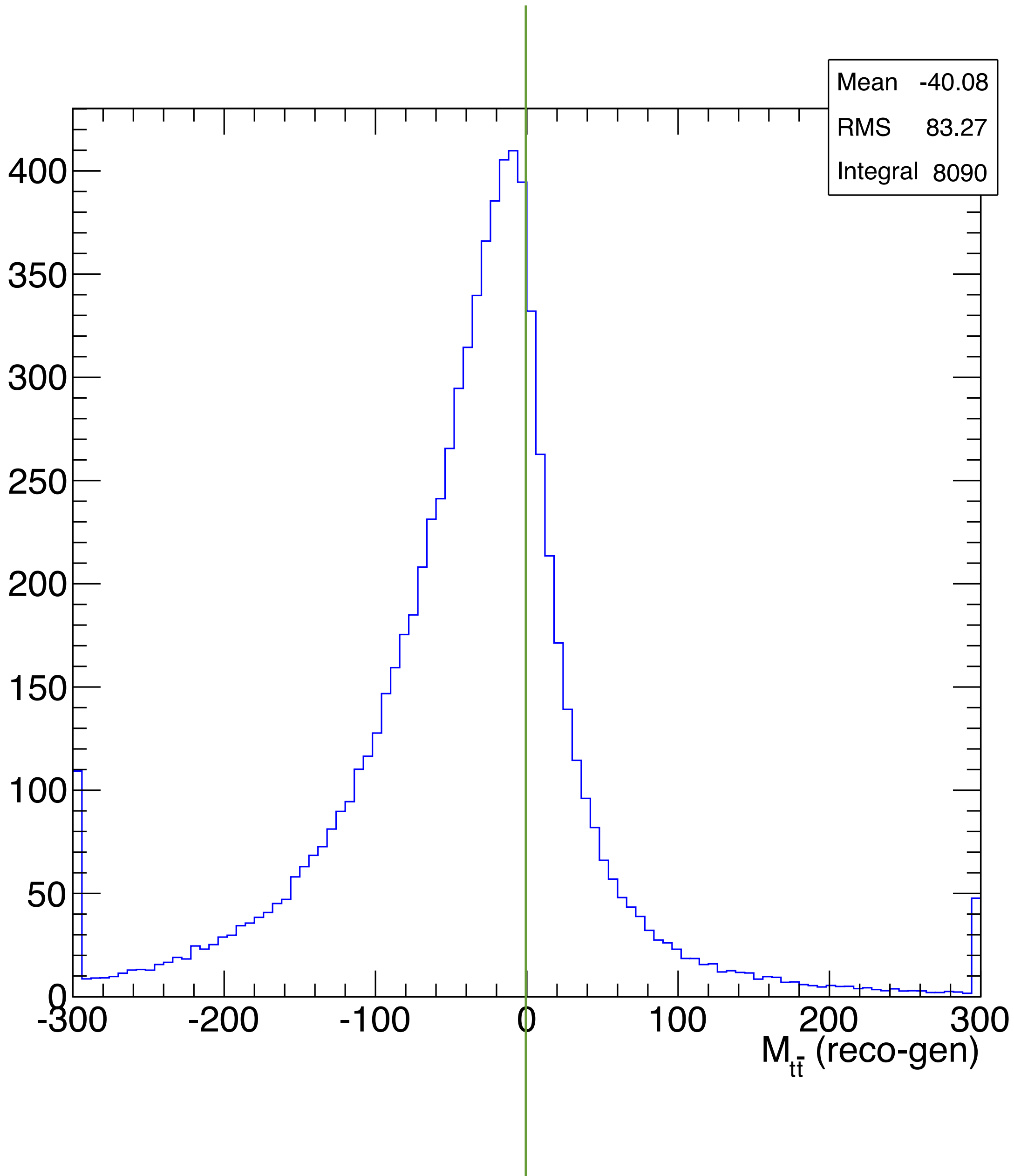
- The bias comes from selecting the solution from a single jet smearing iteration (with no jet smearing, there is no bias)
- Instead, implement smearing as a MC integration over the jet and MET resolution functions
  - first, for each event, constrain the combination of the 2 b jets and 2 leptons to be the one with the largest sum-of-weights (to ensure a constant combination used in the integrand)
  - of the up to 4 possible neutrino solutions for each sampling point of the integration, take the ttbar kinematics from the one with largest weight, w
  - take N samples of each event, using the N integration sampling points with a solution for the ttbar kinematics, each weighted by 1/N
  - propagate the uncertainties under the assumption of 100% correlation between the N samples of each event (this results in pull-widths slightly<1, i.e. slightly over-estimated stat uncertainties)

Results

- Check the performance of the reconstruction using our MC@NLO simulated ttbar sample
  - Plot difference between reconstructed and generator-level quantities for several variables of interest
  - This shows the bias and resolution of the reconstruction

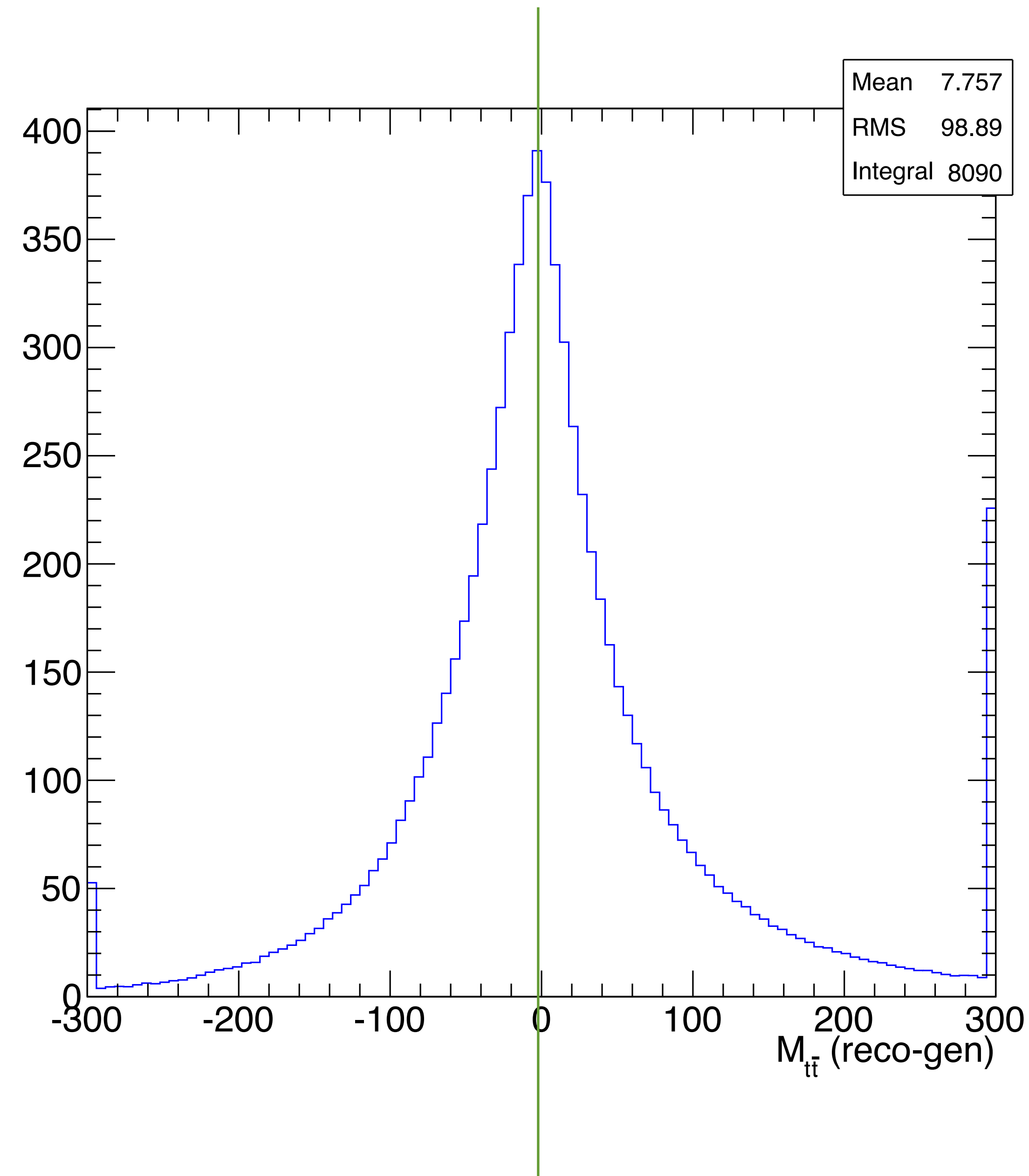
- Several variables plotted on the next few slides
  - the biased distributions (using the single jet smearing iteration with largest weight) are shown on the left
  - the unbiased distributions from integrating over the jet and MET resolution functions are shown on the right

using single iteration with largest weight



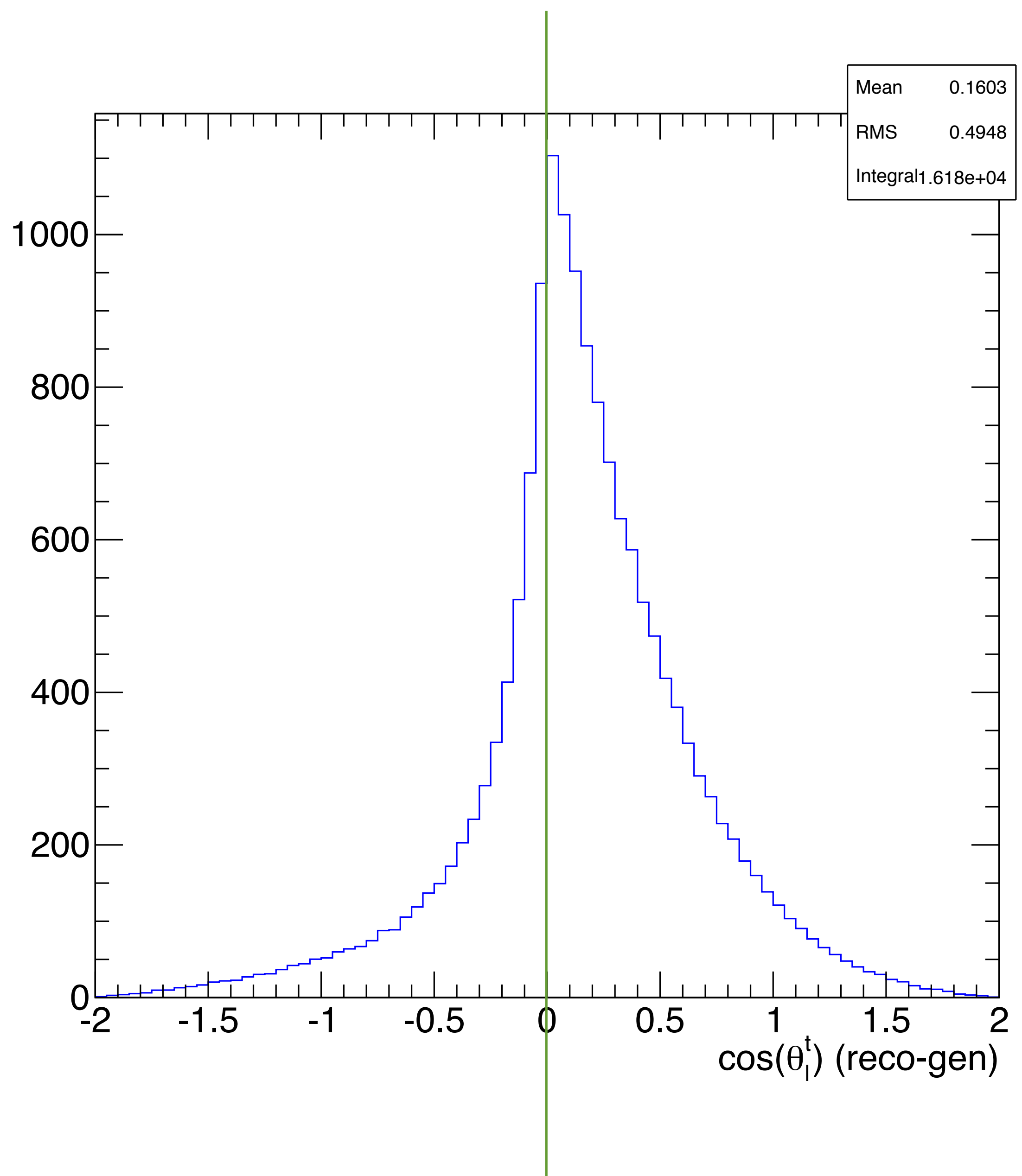
bias towards low Mtt

integrating iterations



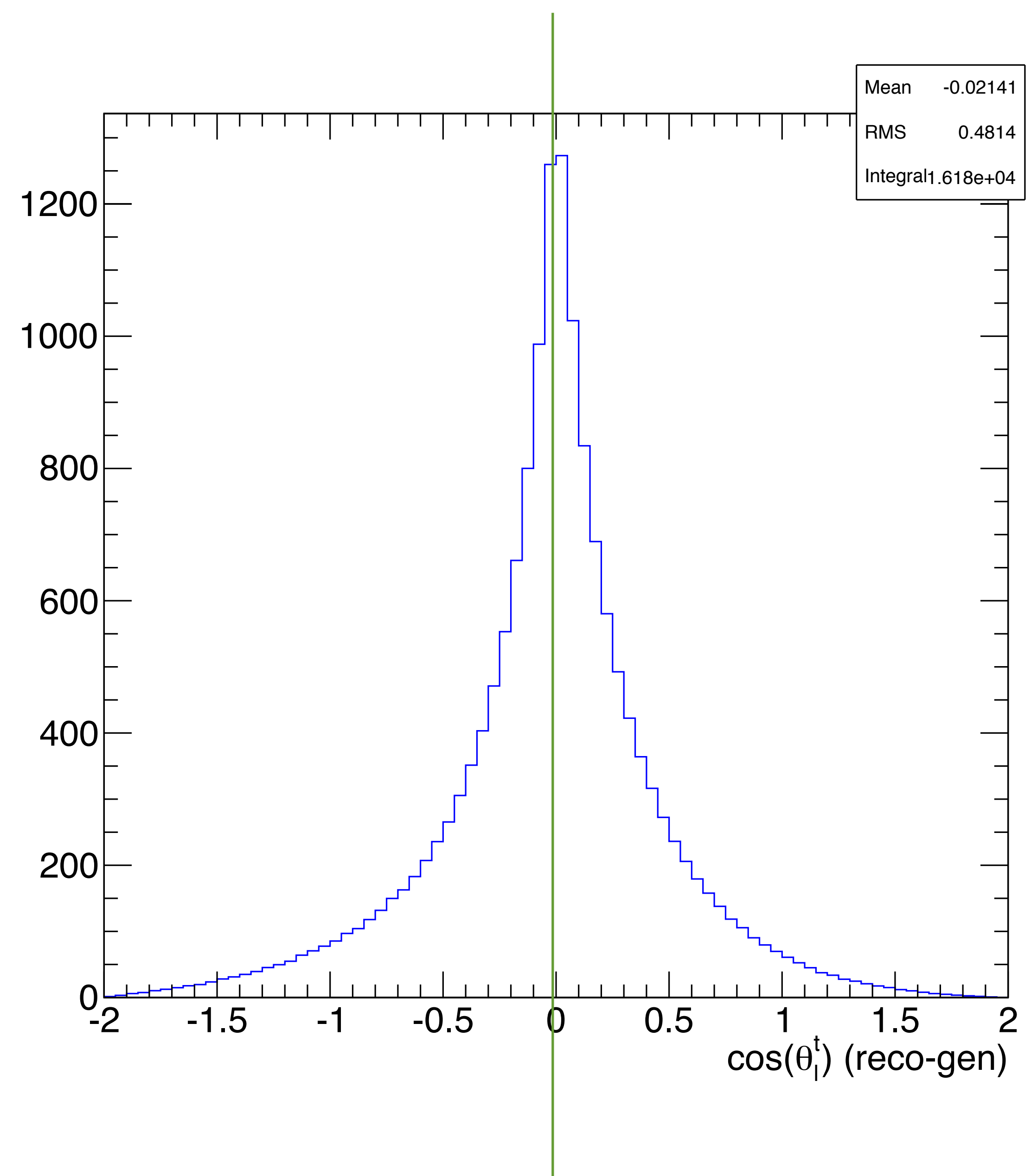
bias removed

using single iteration with largest weight



clear bias

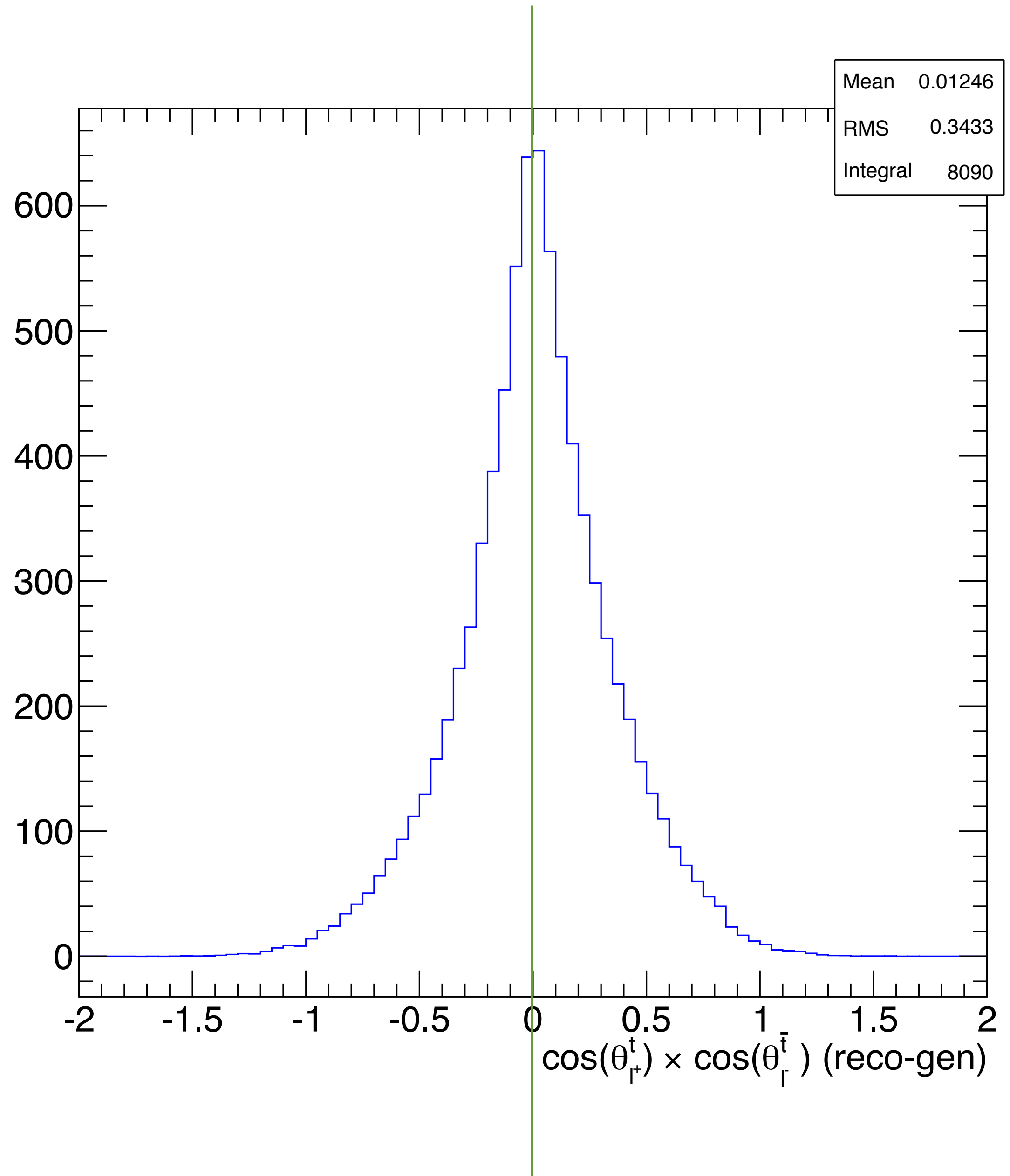
integrating iterations



bias removed

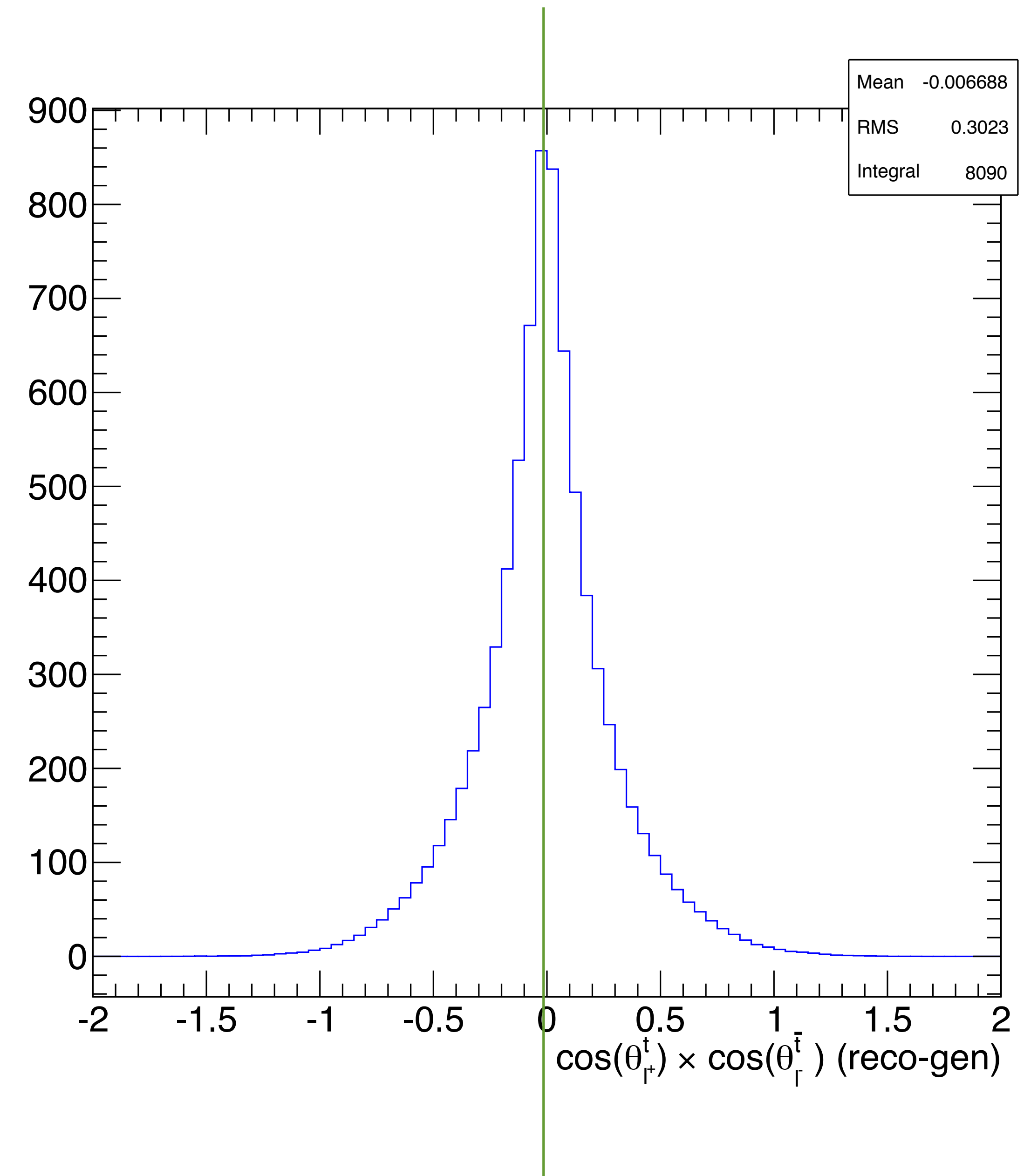
Spin correlation (direct)

using single iteration with largest weight



little bias

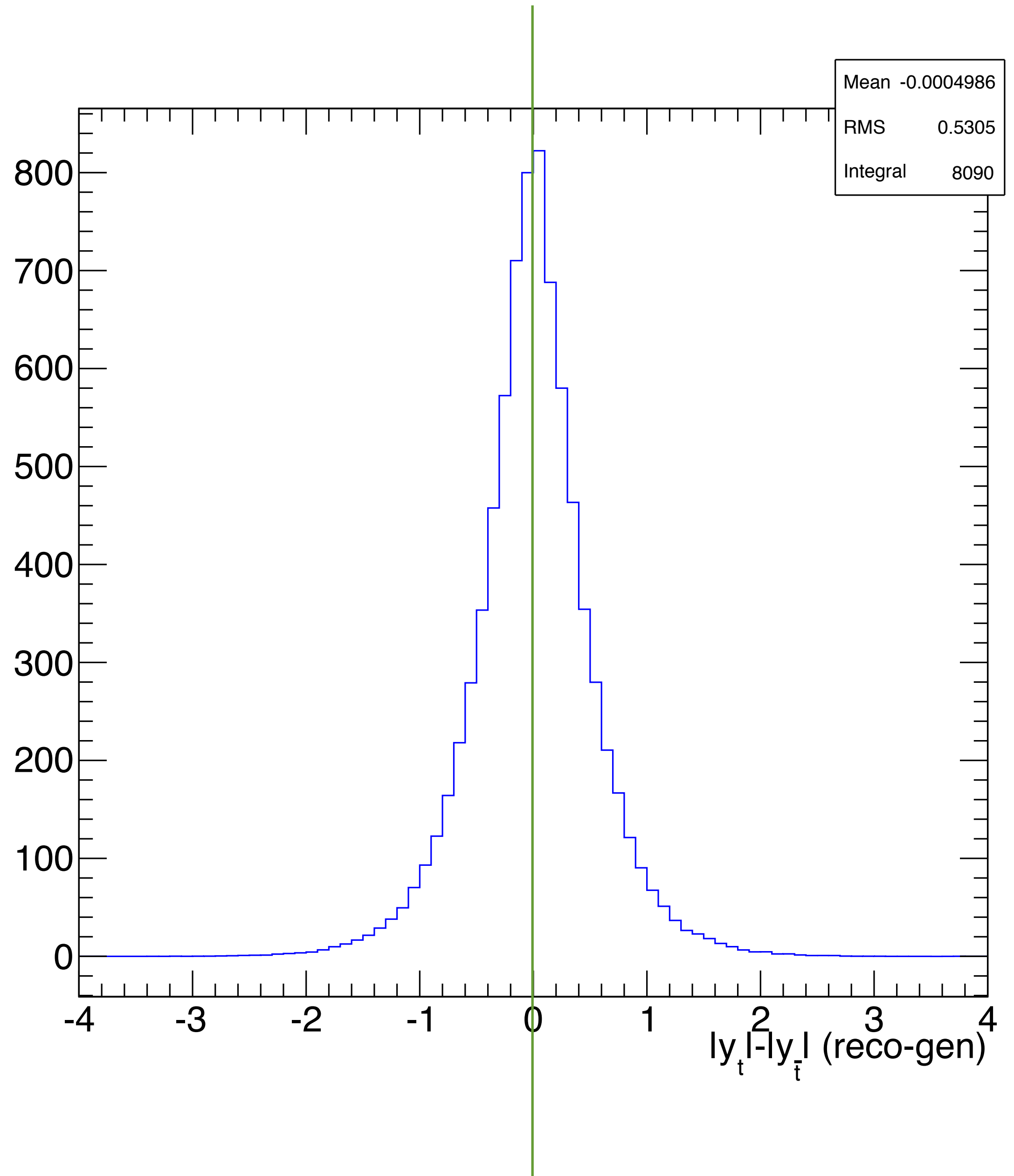
integrating iterations



still little bias, and resolution improved

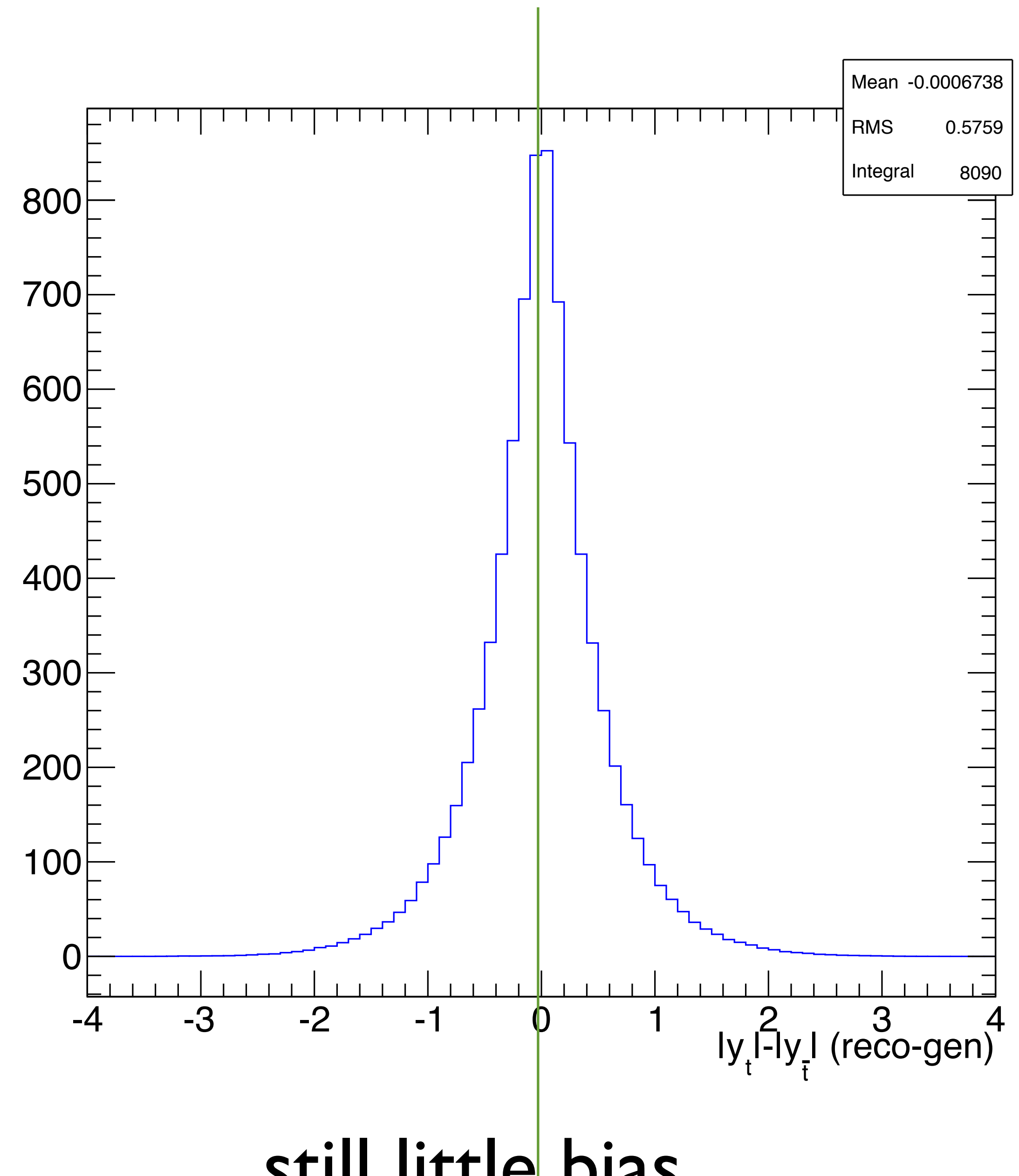
Top charge asymmetry

using single iteration with largest weight



little bias

integrating iterations



still little bias

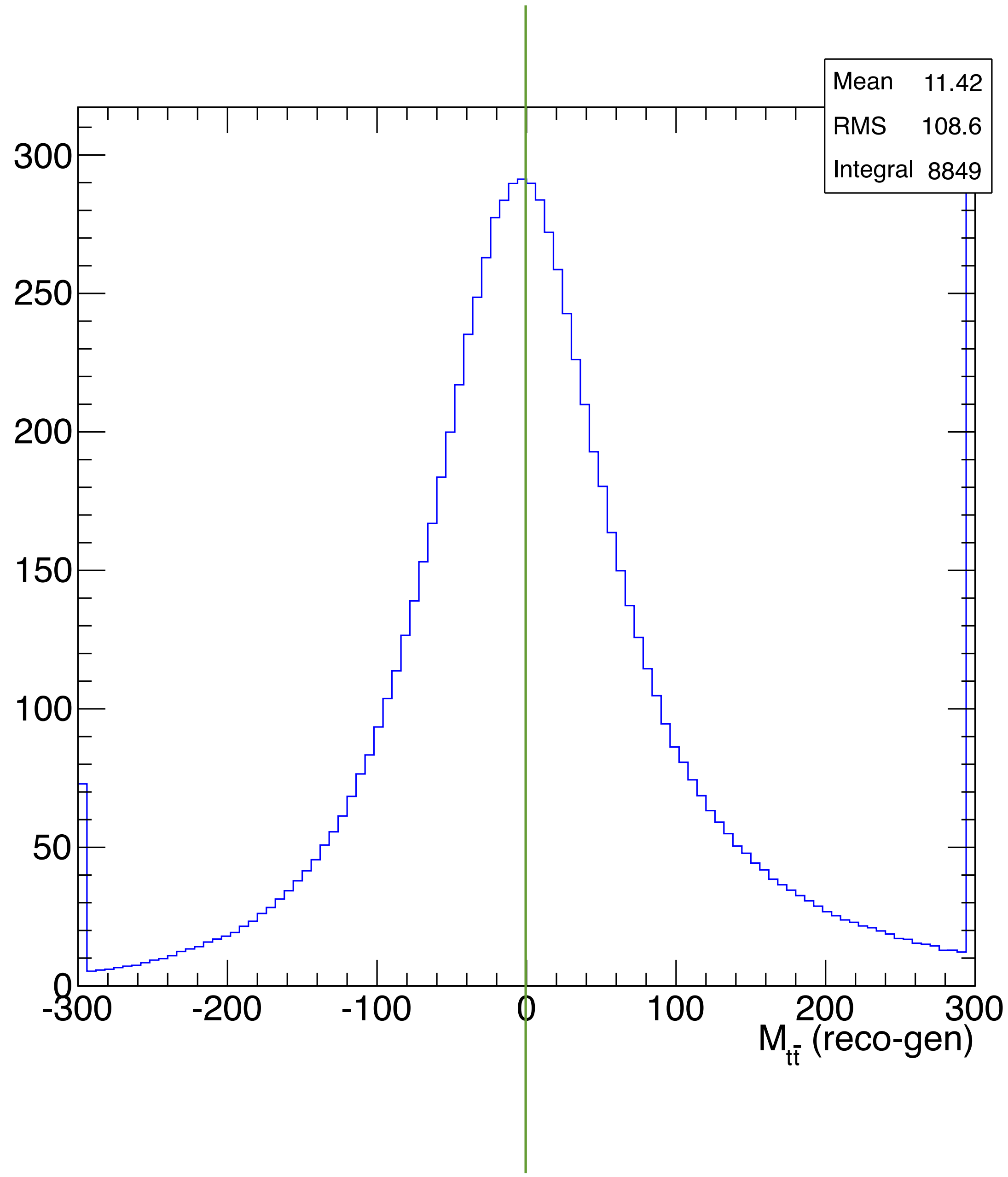
RMS increase only due to extreme tails

Conclusions

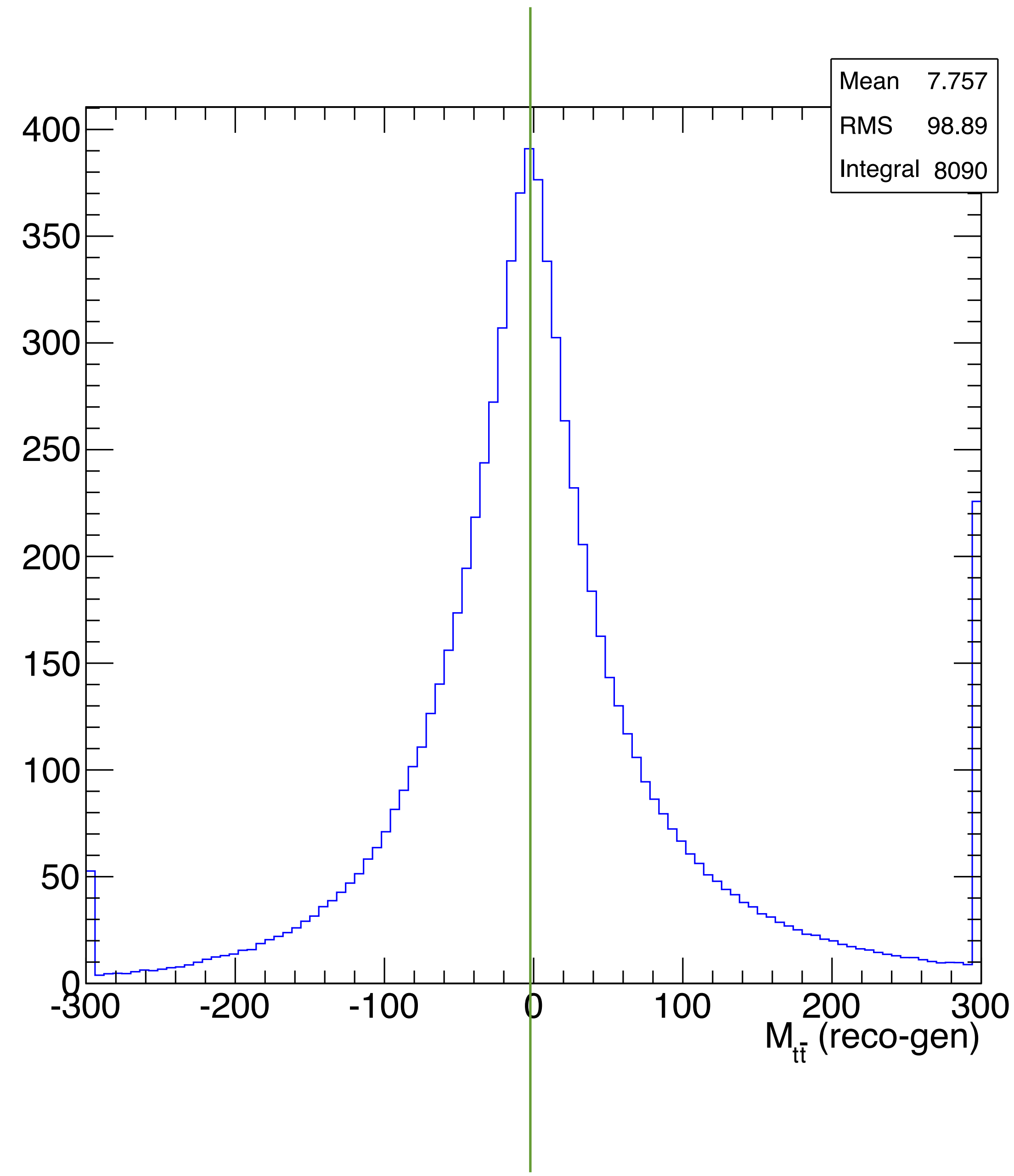
- Fixing m_t instead of scanning from 100-300 GeV improves reconstruction of ttbar system (plots in backup)
- Jet smearing has to be done carefully to avoid biasing the ttbar solution
  - the bias comes from using the AMWT weight to select a single jet smearing iteration to use for the solution
    - the weight does not disfavour the iterations with large (unlikely) smears
  - we removed the bias by integrating over jet resolution functions instead of choosing a single solution
  - in future, it might be possible to adapt the weight to allow selection of a single, unbiased solution
    - this would require the weight to include the jet resolution pdfs, and that we ensure the weight is correctly normalised

Backup

M_{top} scanned 100-300 GeV

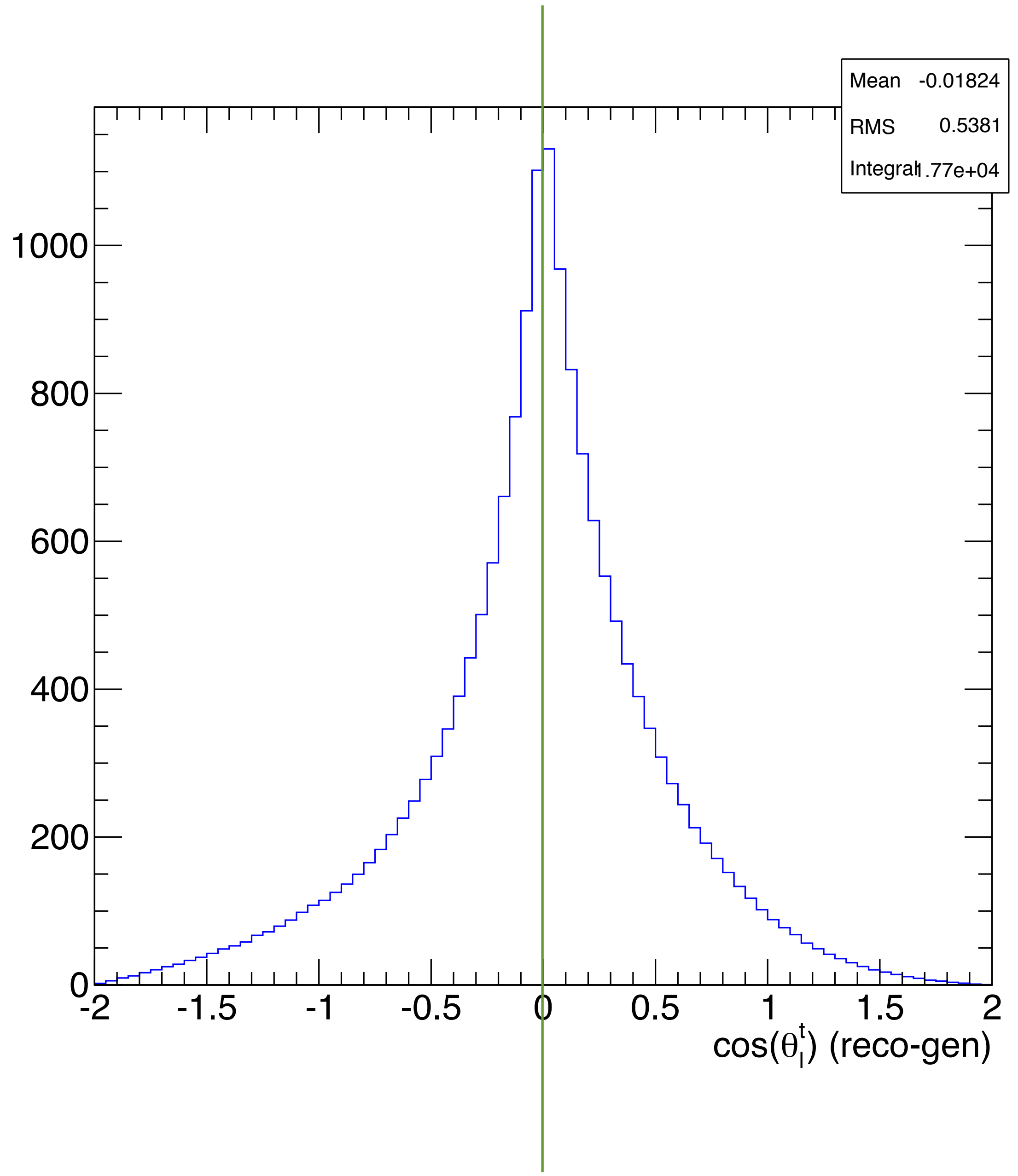


M_{top} fixed to 172 GeV

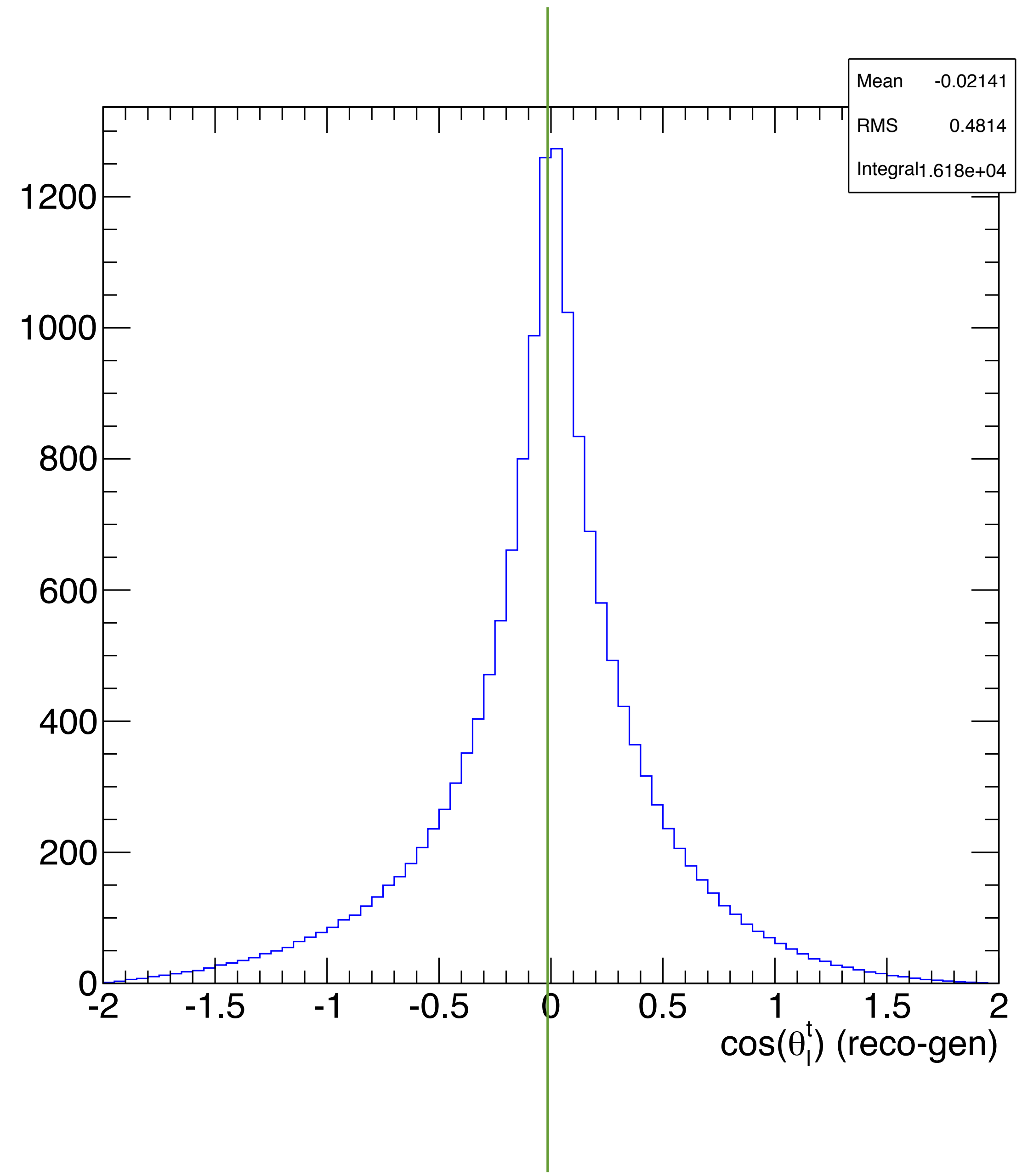


lepton angle in top CM (polarisation)

M_{top} scanned 100-300 GeV

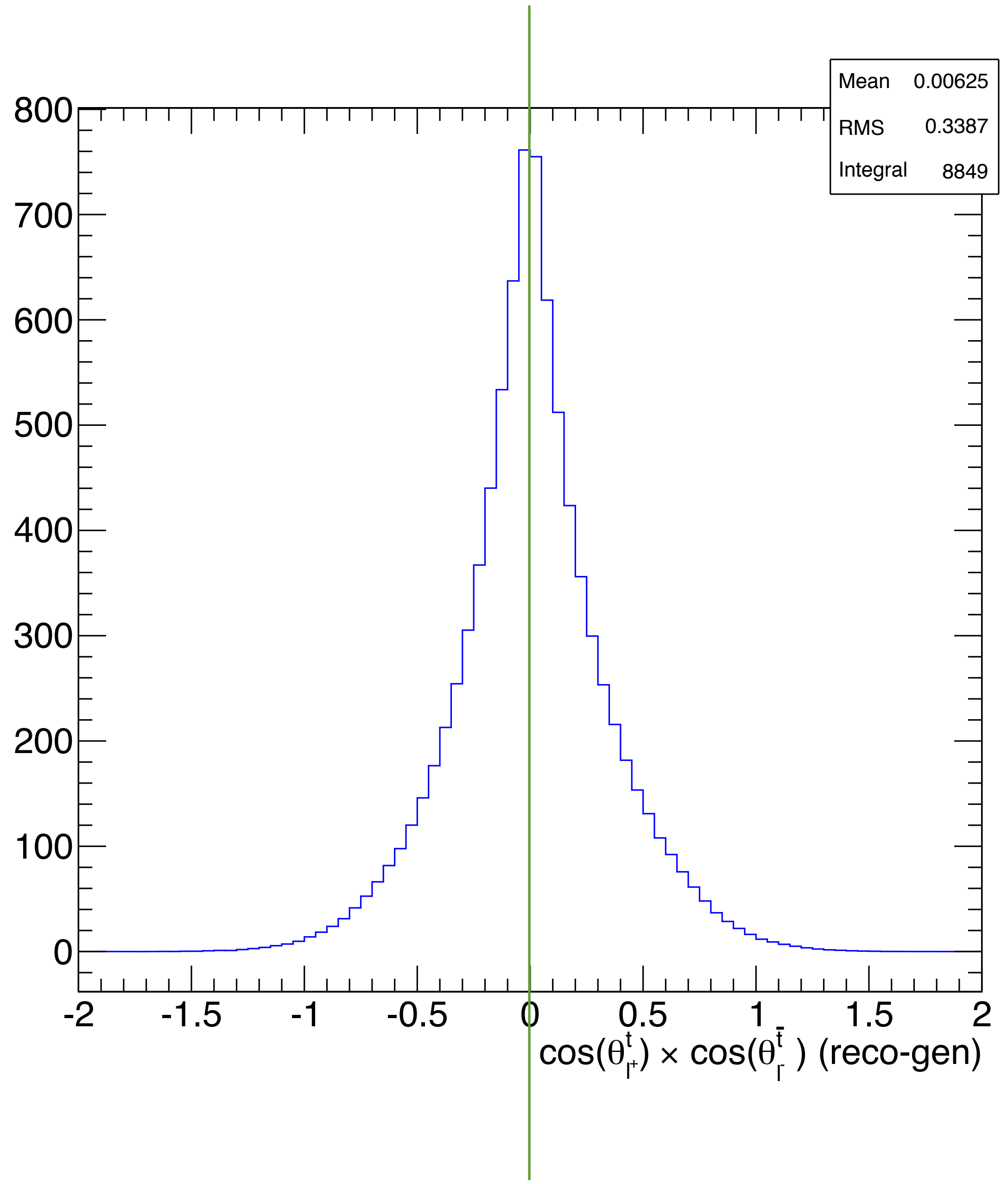


M_{top} fixed to 172 GeV

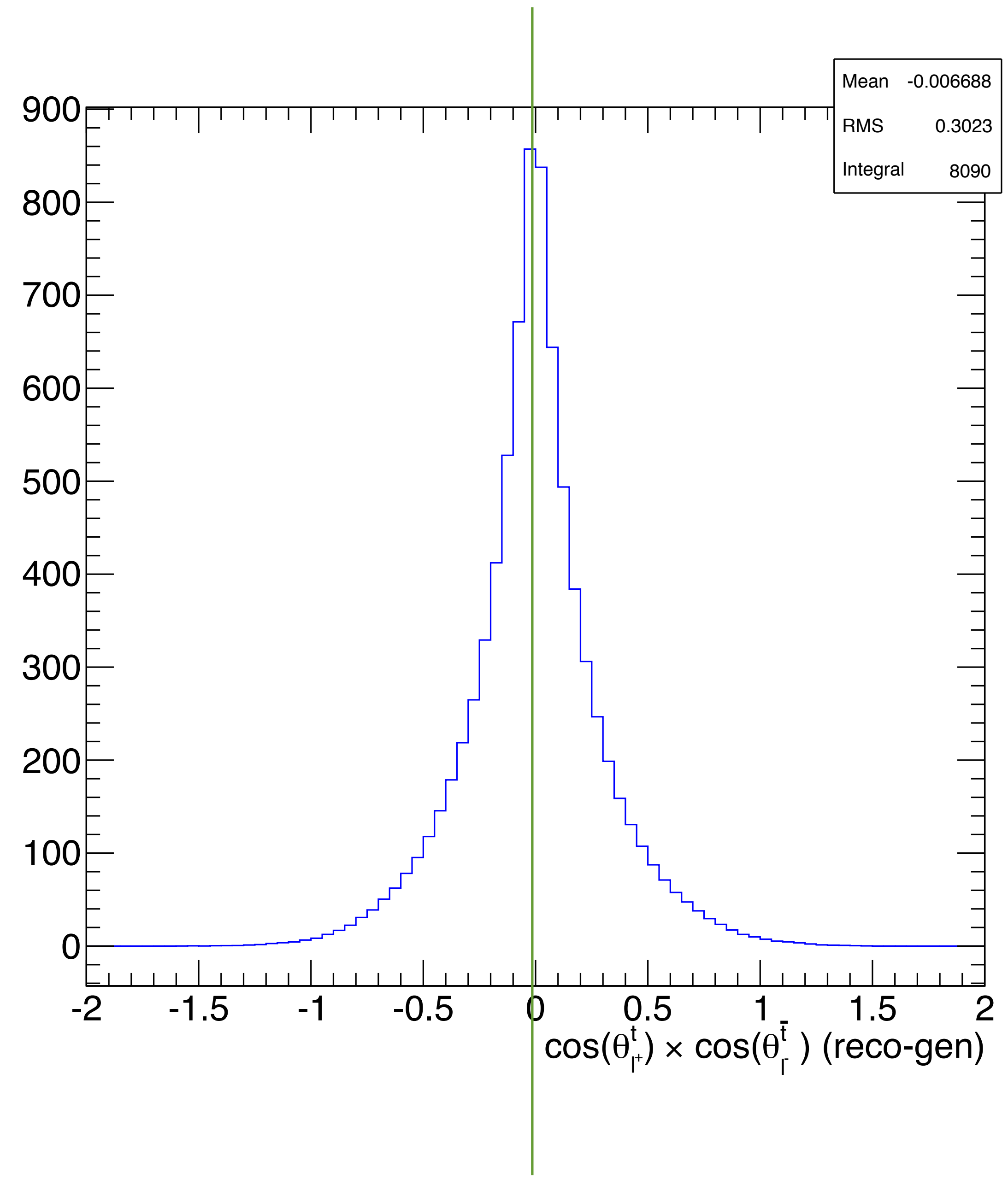


Spin correlation (direct)

M_{top} scanned 100-300 GeV

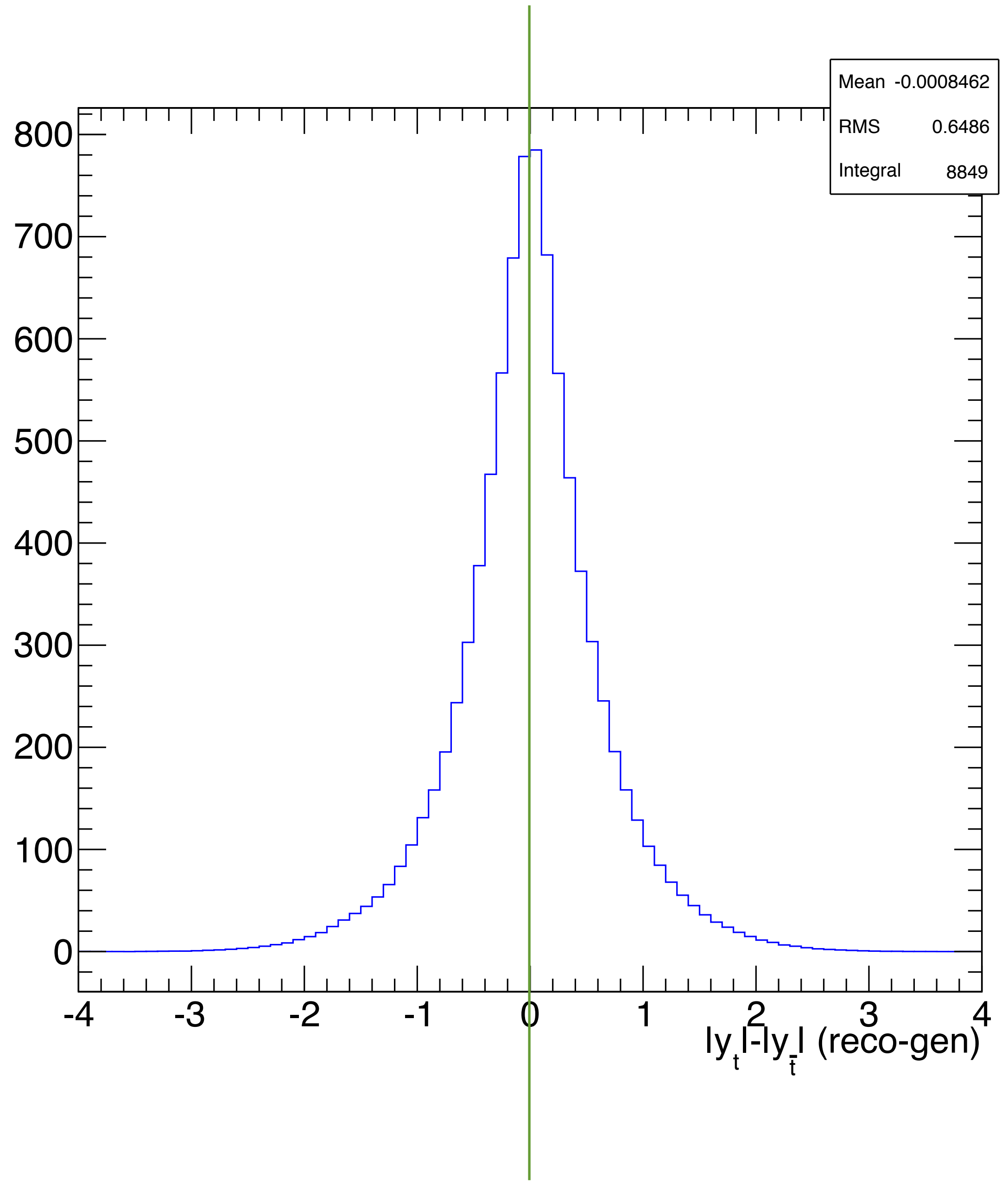


M_{top} fixed to 172 GeV



Top charge asymmetry

M_{top} scanned 100-300 GeV



M_{top} fixed to 172 GeV