Reconstructing the rest frame of $\tau^+ \tau^-$ systems

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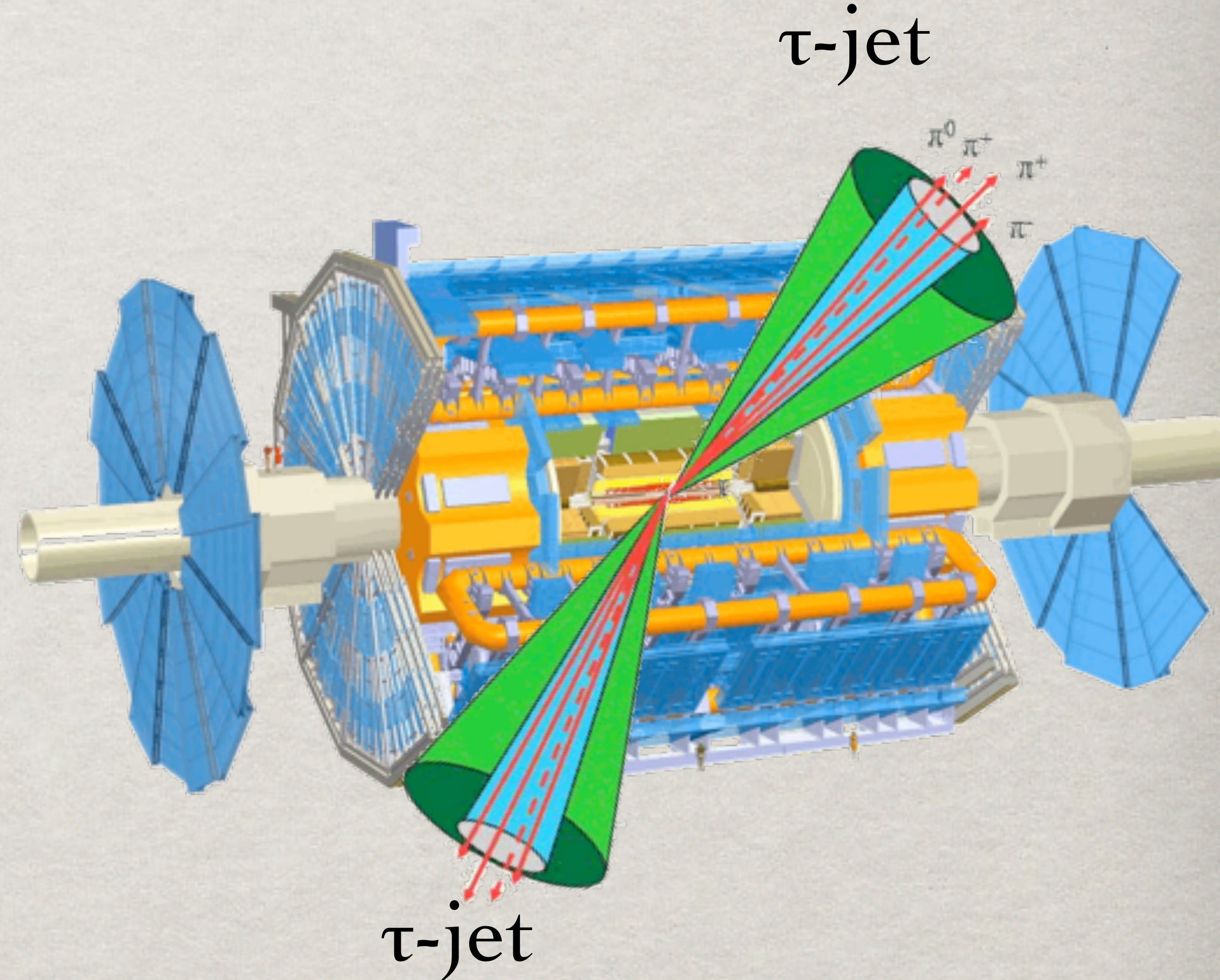
Motivation

- We want to study resonances decaying to a **pair of taus**.
- Unfortunately, some observables are best defined the **rest frame of τ pairs**, especially variables for studying the τ polarisation
    - At LHC, Z and Higgs bosons are produced with **high boost**
    - Due to neutrinos in the τ decays, **no trivial way** exists to reconstruct the resonance rest frame

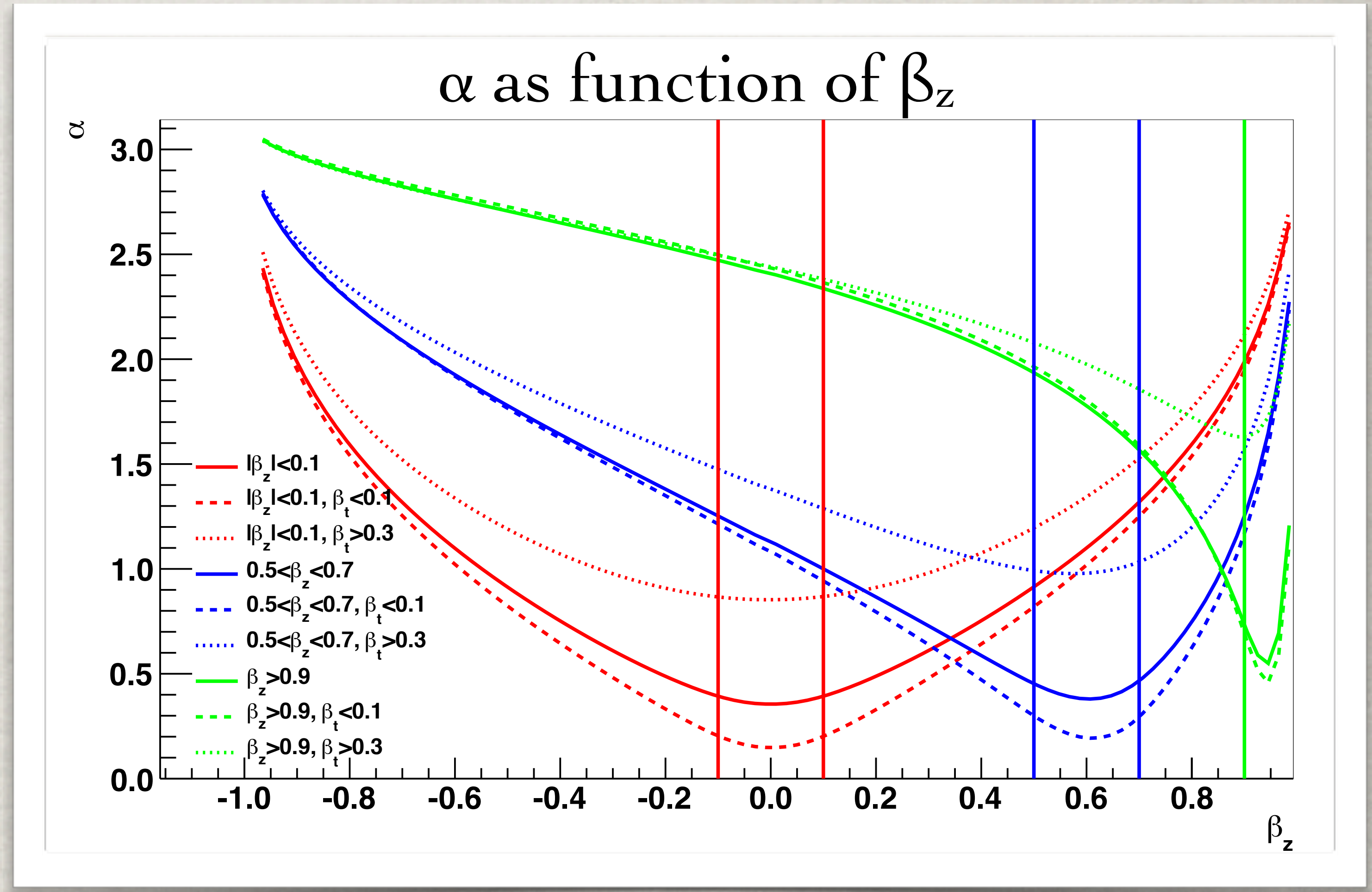
Idea

- For resonances at the Z mass or above, the τ-jets are **collinear**.
  - In resonance rest frame, the visible τ-jets are **nearly back-to-back**.
- Proposed method:
  - Reconstruct rest frame by finding **boost** that makes τ-jets back-to-back



z-Boost Reconstruction

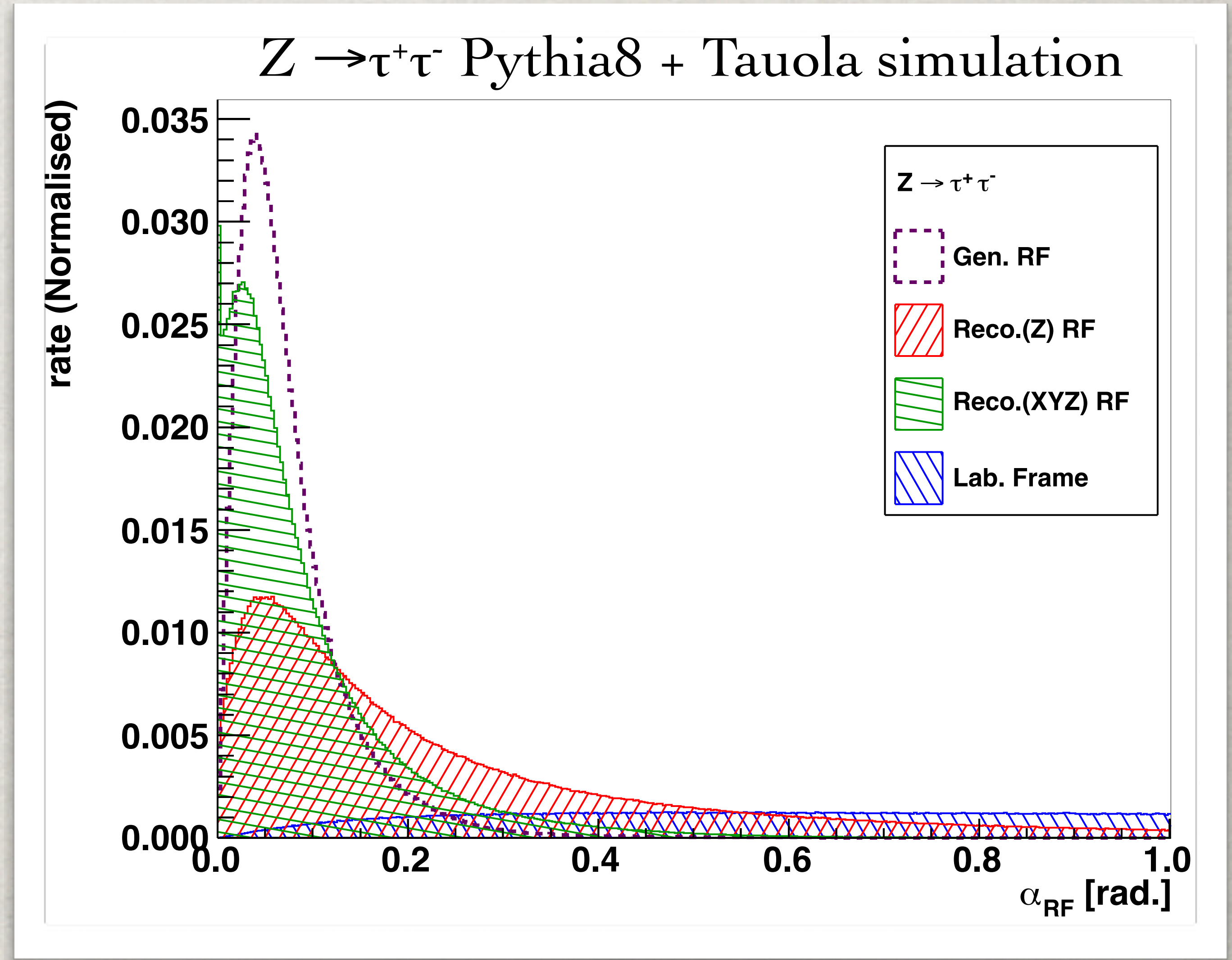
- We define **acollinarity**, α, as the deviation from being back-to-back
- Z and Higgs bosons at LHC are produced with a predominantly **longitudinal** boost
- Search for the boost along the z-axis, β_z, that **minimises α** between the τ-jets



Easy to minimise since α always has single minimum - can be found with a simple binary search

Full Boost Reconstruction

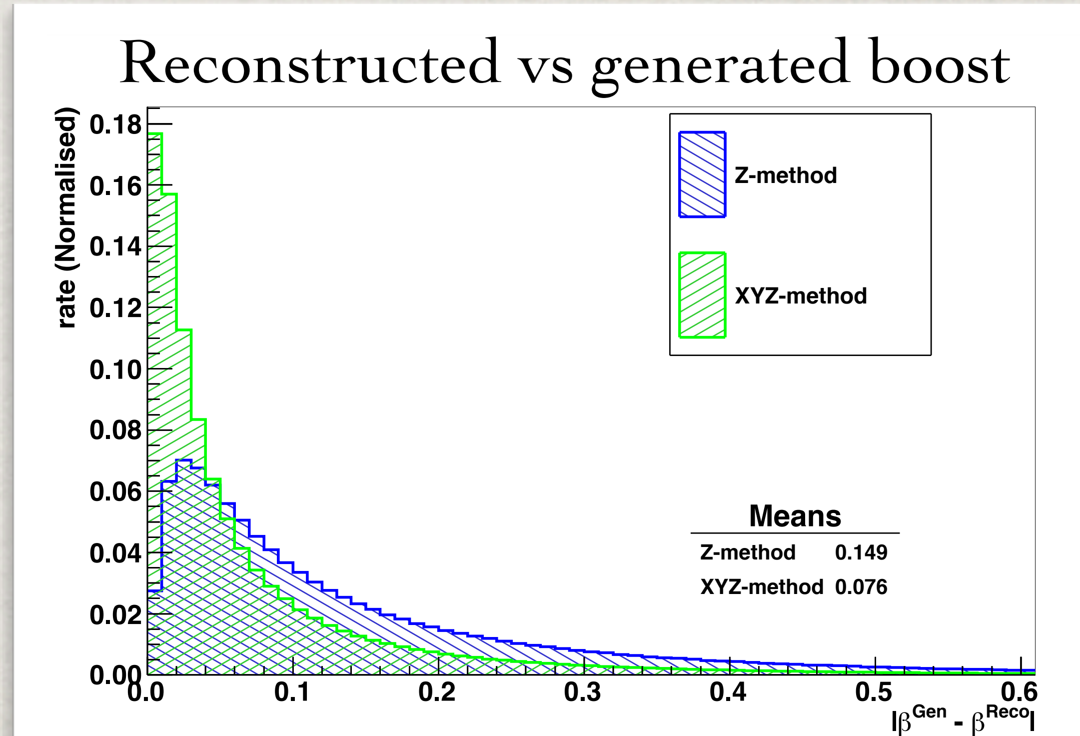
- Method can easily be extended to search for the full boost - not only along the z-axis.
- First find β_z
- Estimate transverse direction by summing up τ-jets p_T and E_T^{miss}
- Finally, search for minimum along transverse direction to find β_T

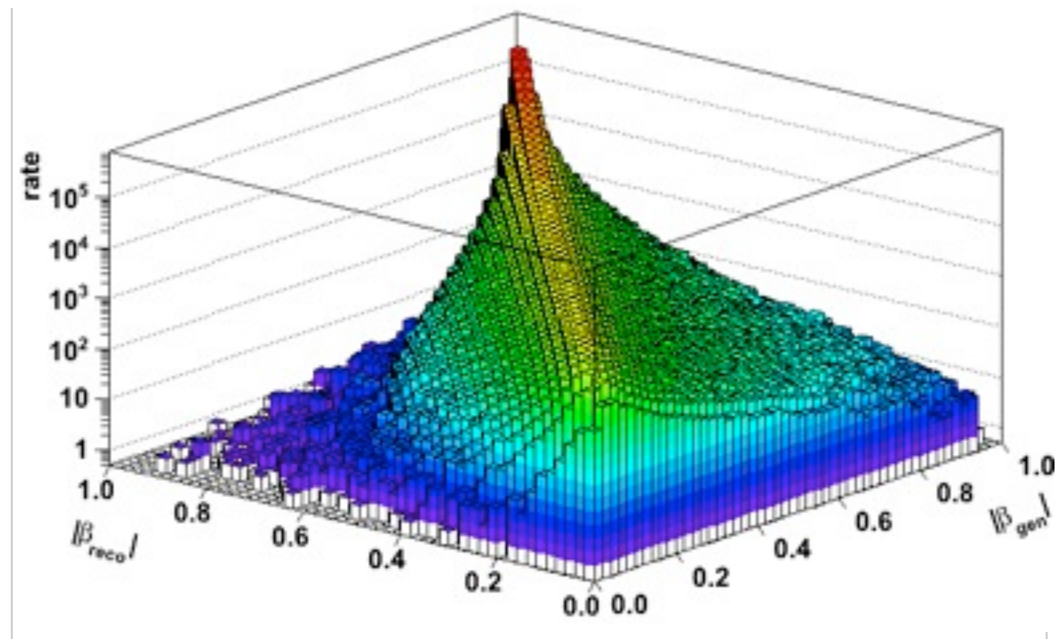


In many cases reconstructing β_z will be sufficient

Performance

- Performance studied on $Z \rightarrow \tau^- \tau^+$ Pythia8+Tauola simulations
- Rest frame is nicely found for all generated boost values
- Better performance in full boost method,
  - However needs accurate transverse direction as input



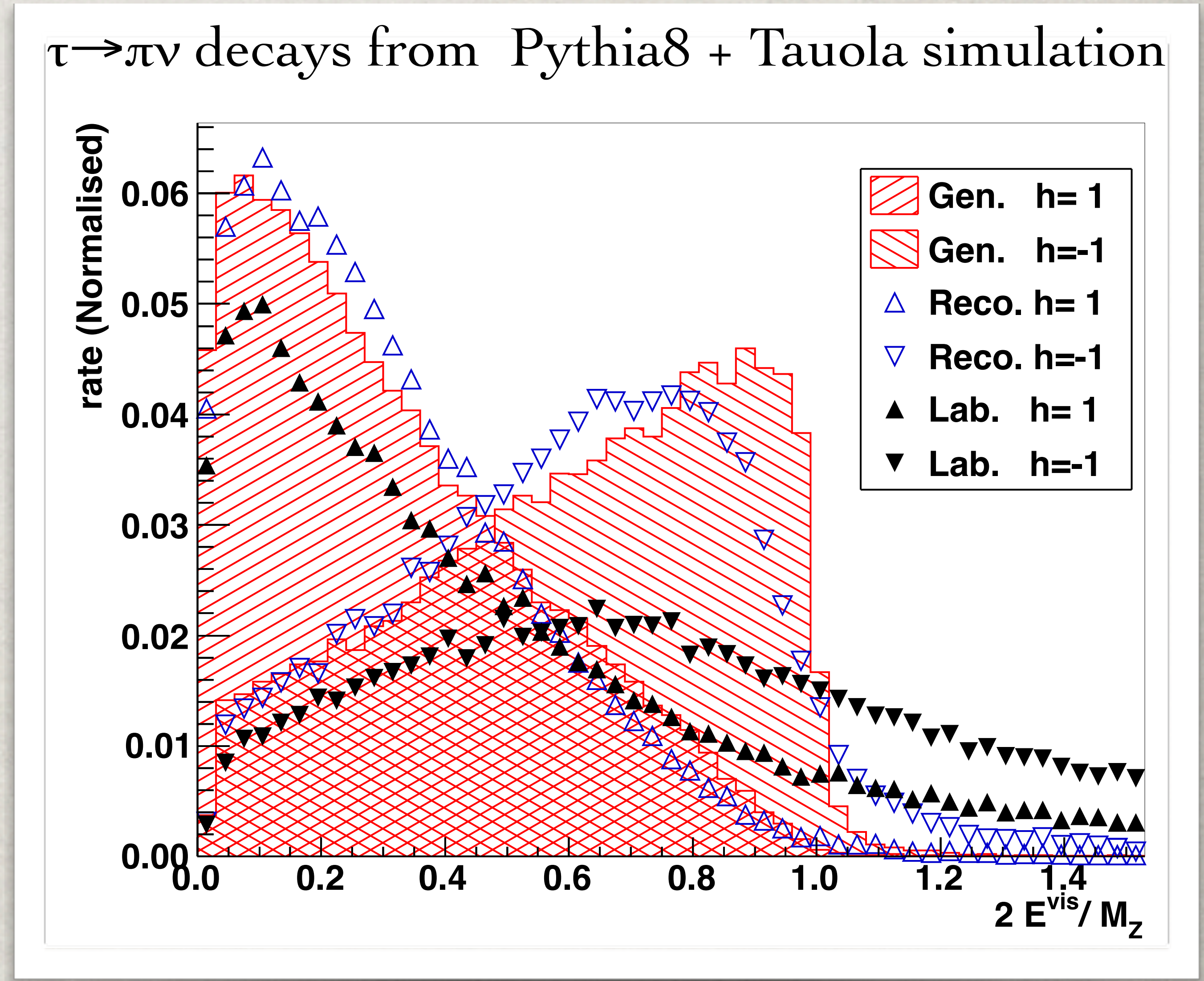


Note: Log scale

Applications

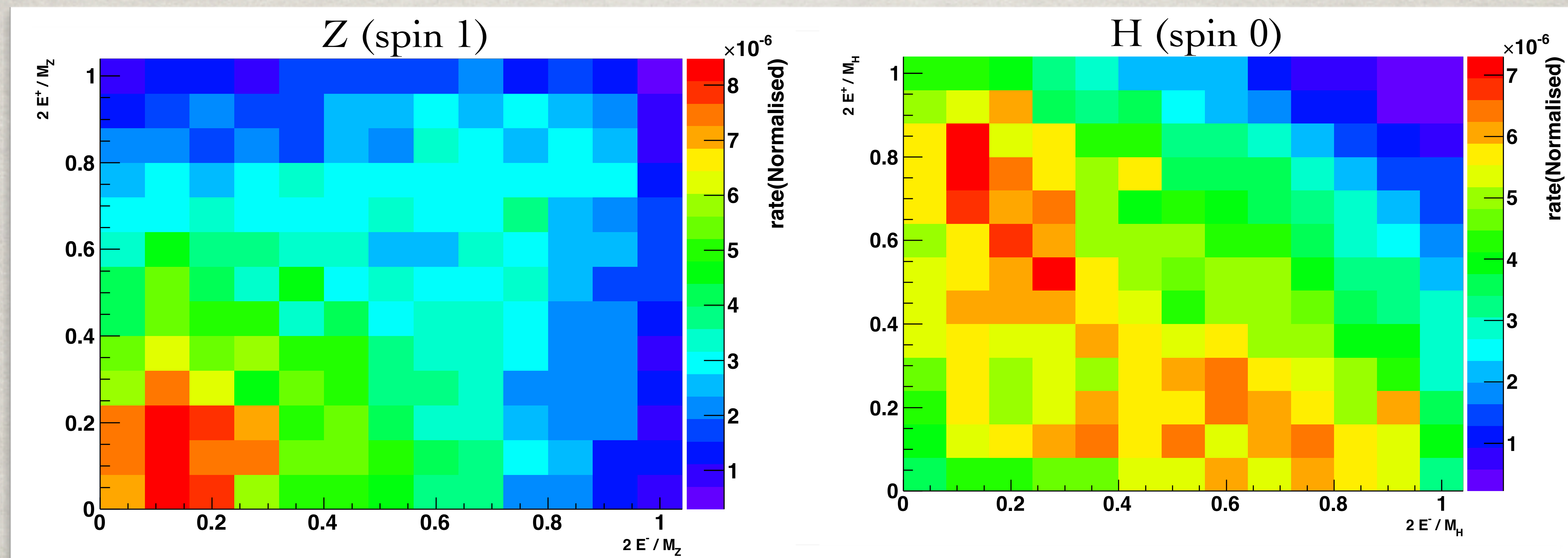
Polarisation study

- Decays of τ-leptons carry information about polarisation
- Effect strongest in $\tau \rightarrow \pi\nu$
  - Looking at $E(\pi^-)/M_Z$
- Effects washed out in detector frame (▲)
- Almost fully recovered in reconstructed frame (△)



Spin Reconstruction

- Polarisation configuration depends on the boson spin
- Spin information can be extracted by studying the polarisation correlation of τ^+ vs. τ^-



Sensitivity to spin

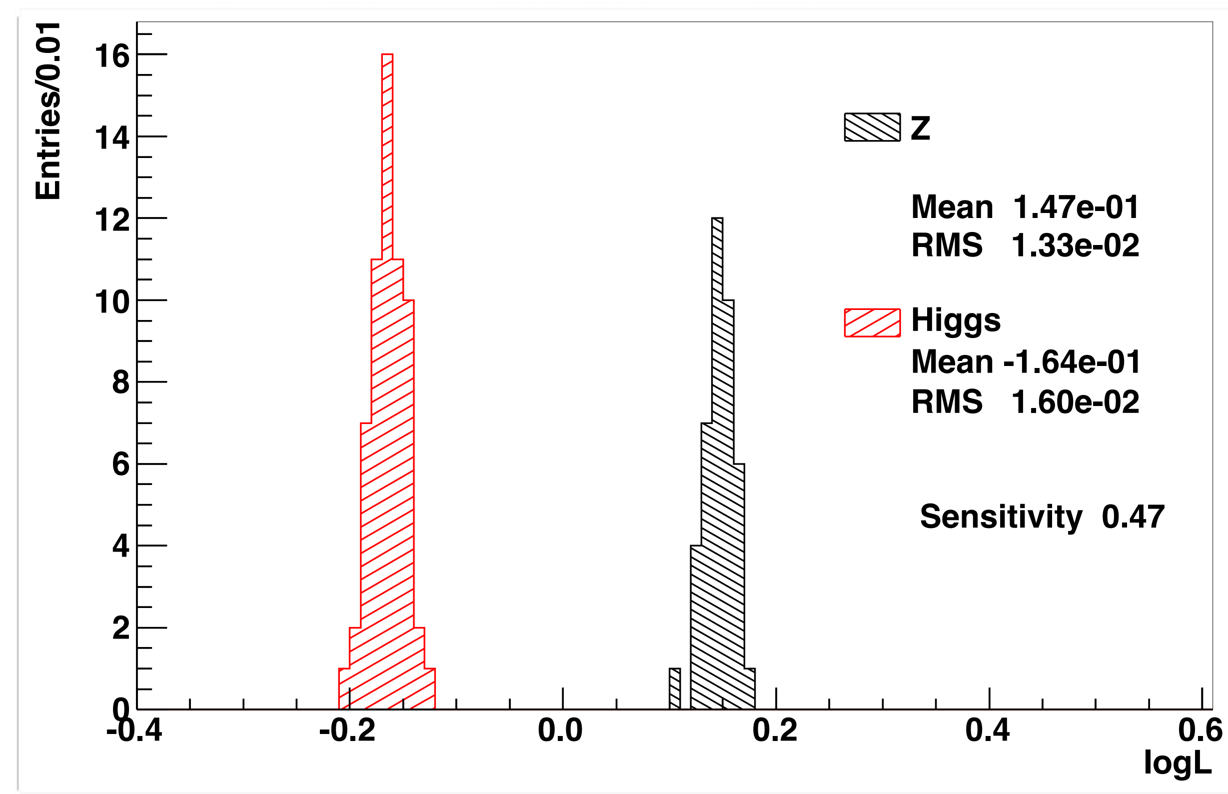
- From these distributions a likelihood function can be created

$$\log \mathcal{L} = \sum_{i=0}^{N} \left(\log(P_1^i) - \log(P_0^i) \right) / N$$

and a sensitivity to spin defined as

$$n_\sigma = S\sqrt{N}$$

Likelihoods for Z and Higgs

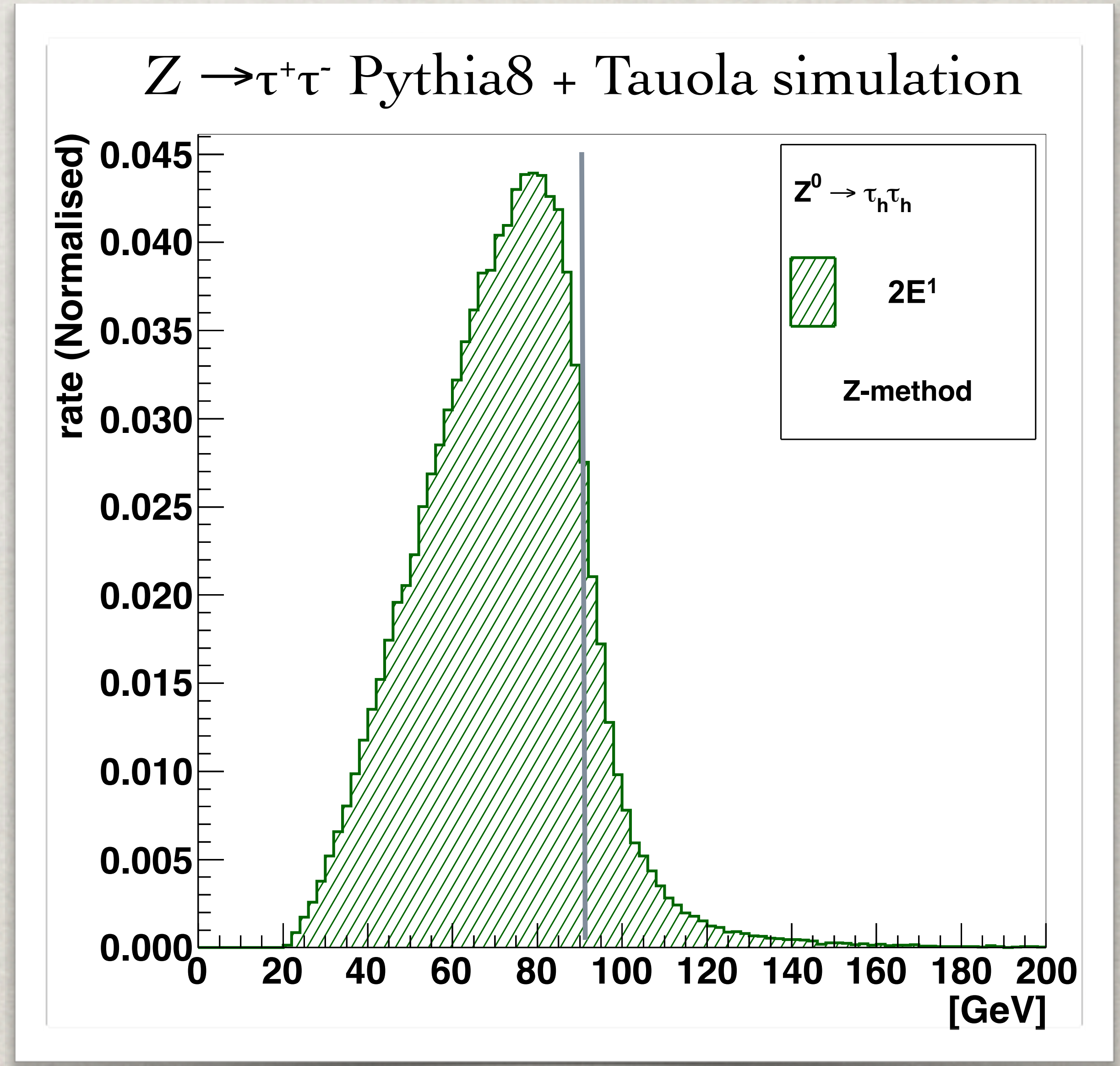


Sensitivity

In detector frame	In recon. frame
0.23	0.47

Alternative Mass Estimation

- Neutrinos in the τ decay makes reconstruction the mass of a resonance non-trivial
- In the resonance rest frame, the leading τ-jet energy will accumulate towards half the resonance mass
- As a simple approximation the **kinematic edge** can be found at the steepest slope in the leading τ-energy distribution



Mass can be extrapolated similarly to W mass measurements

Comparison to other methods

- Both methods can be applied on all events
  - Methods currently used at the LHC, only works for a fraction of suitable event topologies
  - In the region where the Coll. Approx. breaks down, this method can be applied without using E_T^{miss}
- Method is extremely fast and simple
  - more 1000x faster than likelihood method currently used by CMS and ATLAS

Summary and Outlook

- A way of reconstructing rest frame of τ pair resonances and its applications have been presented
  - Method and its applications are published at arxiv:1105.6003 (recently accepted in JHEP)
  - Suitable to all τ decay channels and not necessarily specific to τ pairs
- No detector effects have been included in plots shown
  - However, we are investigating use of the method in ATLAS
- C++ code available on request

Thank you for your attention