Task 4, Higgs to gammatautau

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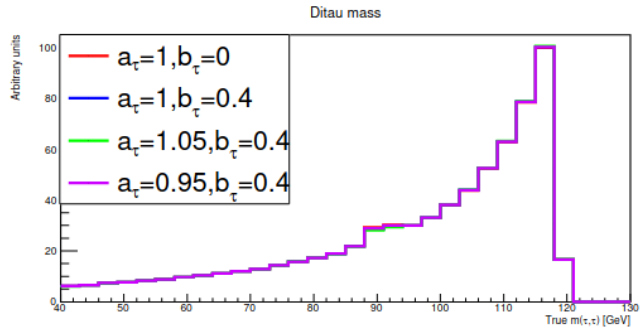
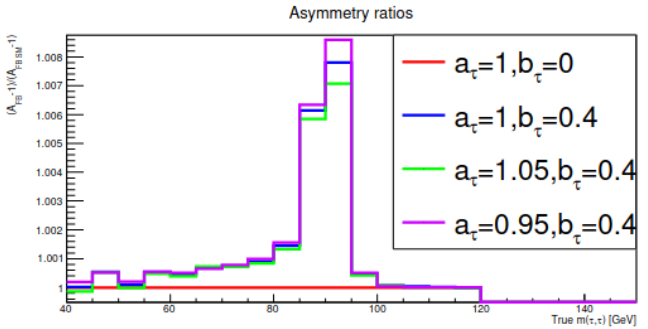
Summary of things done so far

- Reproduced Dibya's ditau mass and asymmetry distributions in reweighthed MC.
- Used minimization procedure to constrain ditau mass shape after reconstruction smears it.
- Problem – too low yields expected with MC, stat. errors too large.
- Question – currently using 3.24e-3 for the BR($h \to \tau\tau\gamma$), does this change with b_τ?

Truth level plots

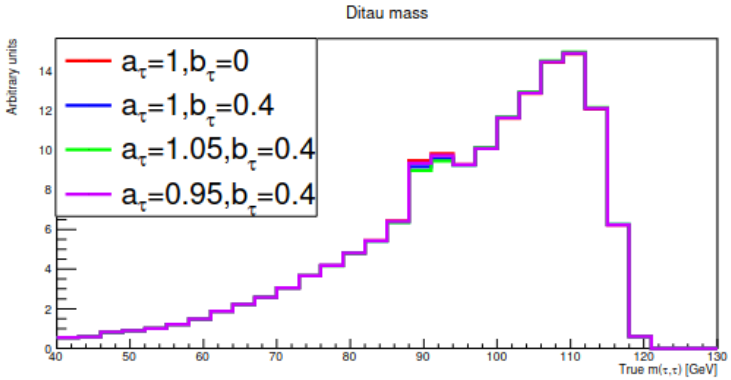


(a) Invariant di-τ mass

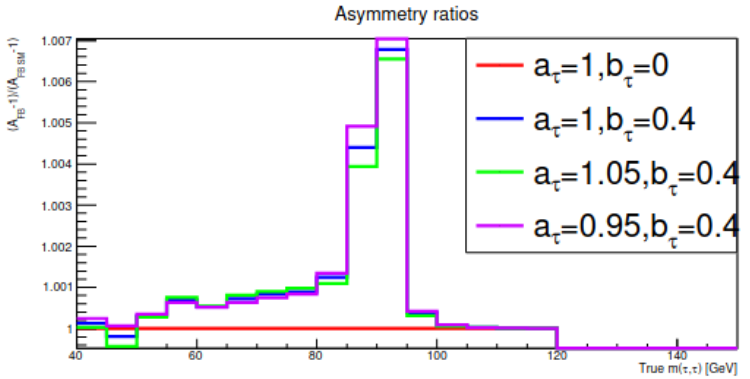


(b) Asymmetry

Truth plots, reco selection

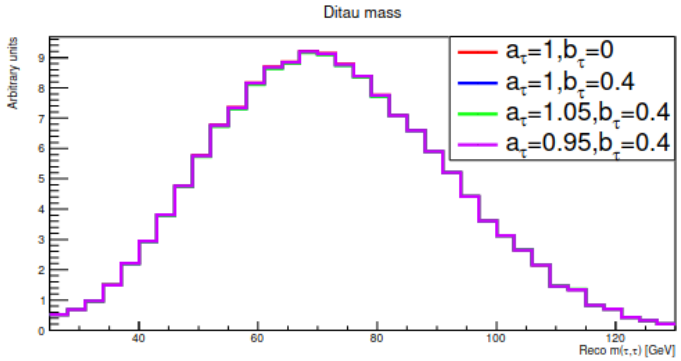


(a) Invariant di-τ mass

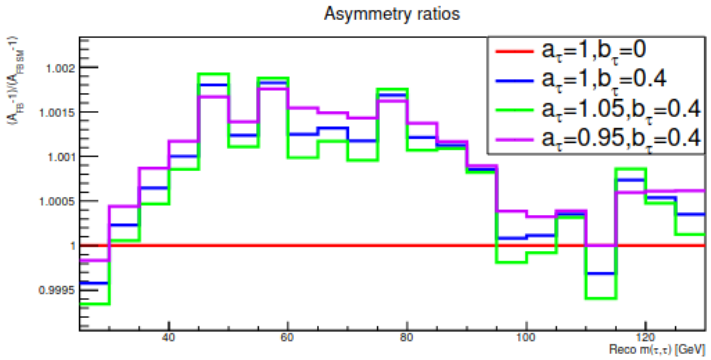


(b) Asymmetry

Reco plots, reco selection



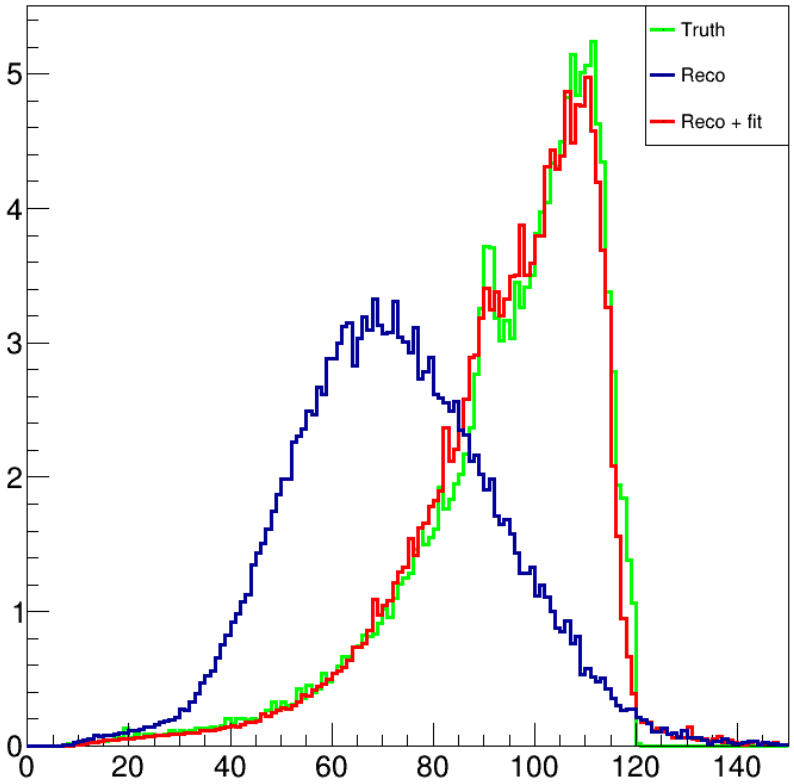
(a) Invariant di-τ mass



Reco-level plots

- At reco level asymmerty (and ditau mass) are smeared.
- Expected, can try to use Higgs mass and MET to constrain the tau energies.
- Recovers a truth-like ditau mamss spectra.
- In a real analysis a much more complicated procedure like MMC would be used, improving the result even more.

Reco before and after



Numbers

From CERN YR4 the Higgs ggF cross-section at 14 TeV is 4.962E+01 or 5.461E+01 pb, depending on the calculation. HL-LHC is expected to provide 3000 fb-1 of data.
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CERNYellowReportPageAt14TeV

(NNLO+NNLL) 4.962E+01 * 3000 * 1000 = ~149mil
(N3LO) 5.461E+01 * 3000 * 1000 = ~164mil

Dibya estimated the branching ratio for H -> tau tau gamma to be 3.24e-3 with 5 GeV photon energy cut and 5 degrees angular cut. Tau decays hadronically ~65% of the time.

(NNLO+NNLL) 3.24e-3 * 148860000.0 * 0.65^2 = 203774
(N3LO) 3.24e-3 * 163830000.0 * 0.65^2 = 224267

So we get, depending on the cross-section used, 204k or 224k events expected.

Asymmetry is concentrated around Z mass peak, roughly 10% of the total number of events. Kinematic selection on reco events reduce it by a factor of 3 further. This gives us at most 8e3 events, statistical uncertainty of $1 - 2\%$. Asymmetry is of the order of 0.5%, hard to detect.

Some numbers

- Use pyhf to estimate expected CLs using several different binnings in the range [80,95] GeV.
- 1 bin: expected CLs = 0.83686220
- 3 bins: expected CLs = 0.82199097
- 5 bins: expected CLs = 0.81447640
- 15 bins: expected CLs = 0.80683240

Bump hunter

- Try to run BumpHunter (there is an open source python implementation)
- Bump edges : [85, 95] (loc=35, width=10)
- Bump mean — width : 90 — 10
- Evaluated number of signal events : 12
- Local p-value — test statistic : 0.41877 — 0.87042
- Local significance : 0.20503
- Global p-value : 1
- But we know where the bump should be (and the found bump matches well what we see by hand), so local p-value is a reasonable approximation.

Conclusions, plans etc

- Standard experimental tools prefer to work with number of events, not ration (=asymmetry itself).
- Can try to do something similar with the shape of the asymmetry itself, but need to think carefully about uncertainties and how best to implement then.
- Anyway, it is clear that with HL-LHC statistics we somewhat lack the number of events.
- What do we do about it?