τ reconstruction at the Muon Collider: Cross section measurement of the H→$\tau\tau$ process

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Jet vs Taugun efficiency

15000 τ (0 ≤ φ ≤ 2π rad; 10° ≤ θ ≤ 170°; 20 ≤ pT ≤ 320 GeV/c)
15000 Z→qqjets & **15000 Z→bbjets**

We define the efficiency as:

$$\varepsilon_{\text{Jets}}^{(\text{after cut})} = \frac{N_{\tau}^{\text{reco}}}{2\ N_{\text{evt}}},$$

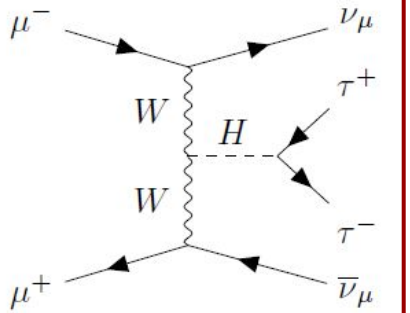
$$\varepsilon_{\text{Taugun}}^{(\text{after cut})} = \frac{N_{\tau}^{\text{reco}}}{N_{\text{evt}}},$$

Cuts: number of taus generated = 0 for jets; number of charged track != 2 & 4

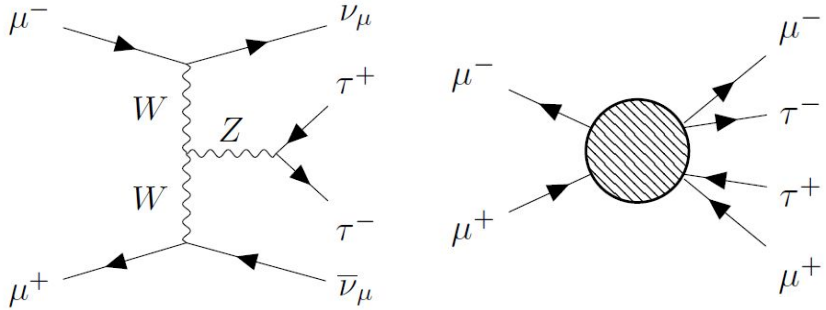
Sample	Efficiency (after cut)
TauGun	0.903
BBjet	0.307
QQjet	0.344

Signal and Backgrounds samples

Signal: H → ττ



Backgrounds: Z → ττ, μμ → ττμμ



Process	Generated events	ϵ	σ[fb]	Expected events ($10\,\mathrm{ab}^{-1}$)
$\mu^+\mu^- \to H\nu_\mu\bar{\nu}_\mu,\ H \to \tau^+\tau^-$	100 k	0.10	52.17	52170
$\mu^+\mu^- \to Z\nu_\mu\bar{\nu}_\mu,\ Z \to \tau^+\tau^-$	100 k	0.08	127.4	101920
$\mu^+\mu^- \to \tau^+\tau^-\mu^+\mu^-$	100 k	0.02	288.6	57720

ϵ after requirement: 2 reconstructed τ_hs with opposite charges and with p_T(reco)>20 GeV

σ given by MadGraph

Expected events: $N = \epsilon \cdot \sigma \cdot \mathscr{L}$, for a luminosity of 10 ab^{-1}

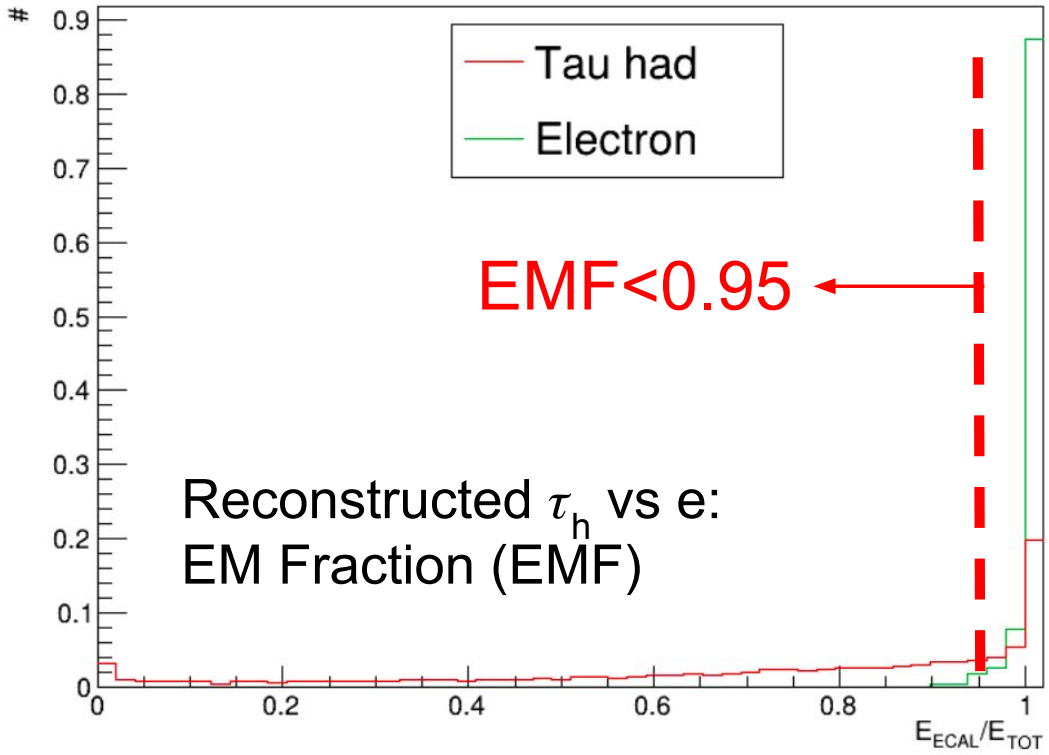
Cut on Electromatic Fraction (EMF)

To avoid generated electrons misidentified as pions:

⇒ cut on EMF < 0.95

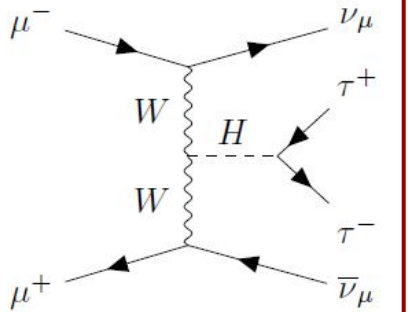
Remove around 25% of hadronic taus

We expect 50% of hadronic tau pairs to be removed

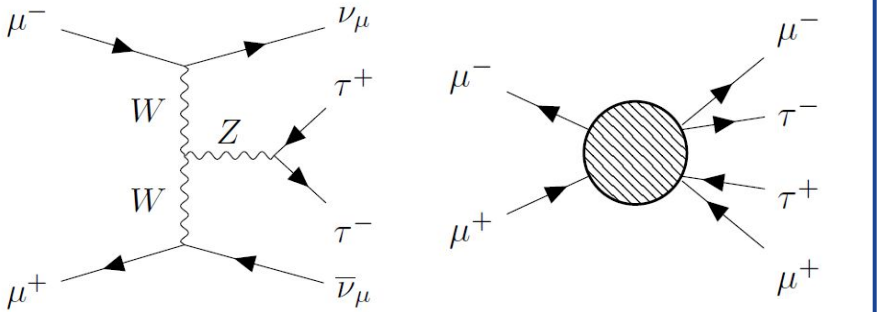


Signal and Backgrounds samples

Signal: H → ττ



Backgrounds: Z → ττ, μμ → ττμμ



Process **EMF Cut**	Generated events	ϵ	σ[fb]	Expected events ($10\,\mathrm{ab}^{-1}$)
$\mu^+\mu^- \to H\nu_\mu\bar{\nu}_\mu,\ H \to \tau^+\tau^-$	100000	0.05	52.17	26085
$\mu^+\mu^- \to Z\nu_\mu\bar{\nu}_\mu,\ Z \to \tau^+\tau^-$	100000	0.04	127.4	50960
$\mu^+\mu^- \to \tau^+\tau^-\mu^+\mu^-$	100000	0.01	288.6	28860

ϵ after requirement: 2 reconstructed τ_hs with opposite charges and with p_T(reco)>20 GeV and EMF < 0.95 (**reduce by 2 the efficiency**)

σ given by MadGraph

Expected events: $N = \epsilon \cdot \sigma \cdot \mathscr{L}$, for a luminosity of 10 ab^{-1}

Fit procedure & results

Start from Signal (H) and Background (DY and μμ$\tau\tau$); build PDFs (Probability density function) templates; extract S and B from fit

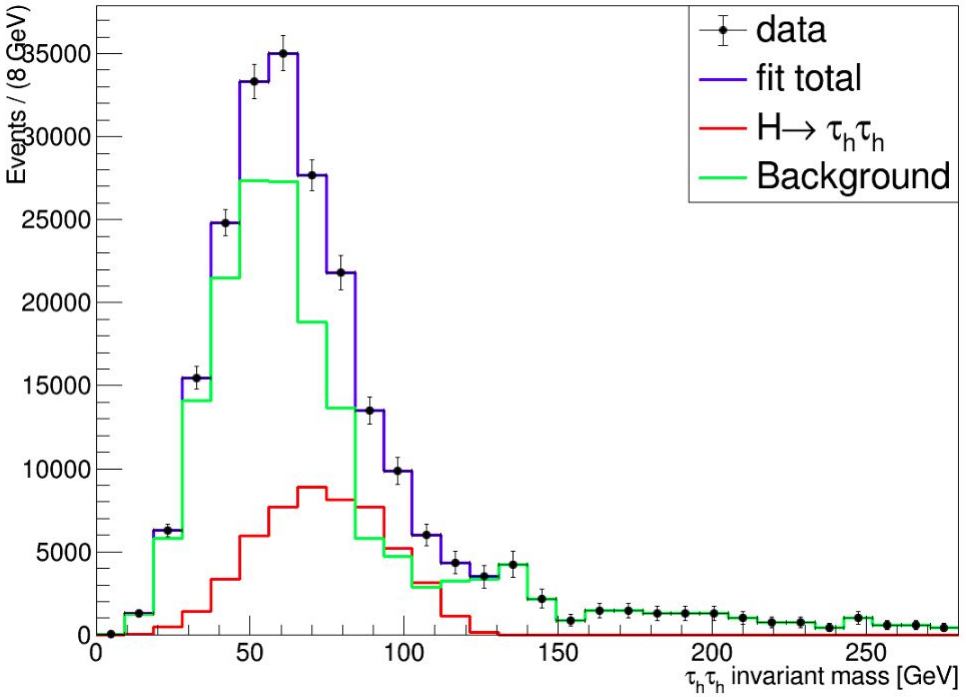
100 000 RooFit toy experiments → pseudo-data via Poisson fluctuations

Each toy: combined fit of signal + background → extract best estimates of event yields for Nsig & Nbkg

Extract cross section:

$\sigma(H \to \tau^+\tau^-) = \frac{N}{\epsilon L}$, *L* is Luminosity, ϵ is efficiency after cuts, *N* is signal event yield

We obtain: $\frac{\Delta\sigma}{\sigma} = 1.1\%$ & $\frac{\Delta\sigma}{\sigma} = 1.4\%$ **with EMF cut**



Visible Invariant mass for hadronic τ decay for signal and background

Conclusions and Next Steps

⇒ obtain: Δσ/σ=1.1% (1.4% with EMF cut) statistical uncertainty

This result can be compared to a previous analysis at **3 TeV** CoM giving **5.3% statistical uncertainty**

The uncertainty on the **H→ττ** cross section can roughly be compared with the sensitivity on the κ_τ parameter. This result is competitive to κ_τ estimated values from **FCC** (**0.44%**) and **HL-LHC** (**1.9%**)

Next steps:

- Build Misidentification rate for Jets with the requirements we apply to the analysis

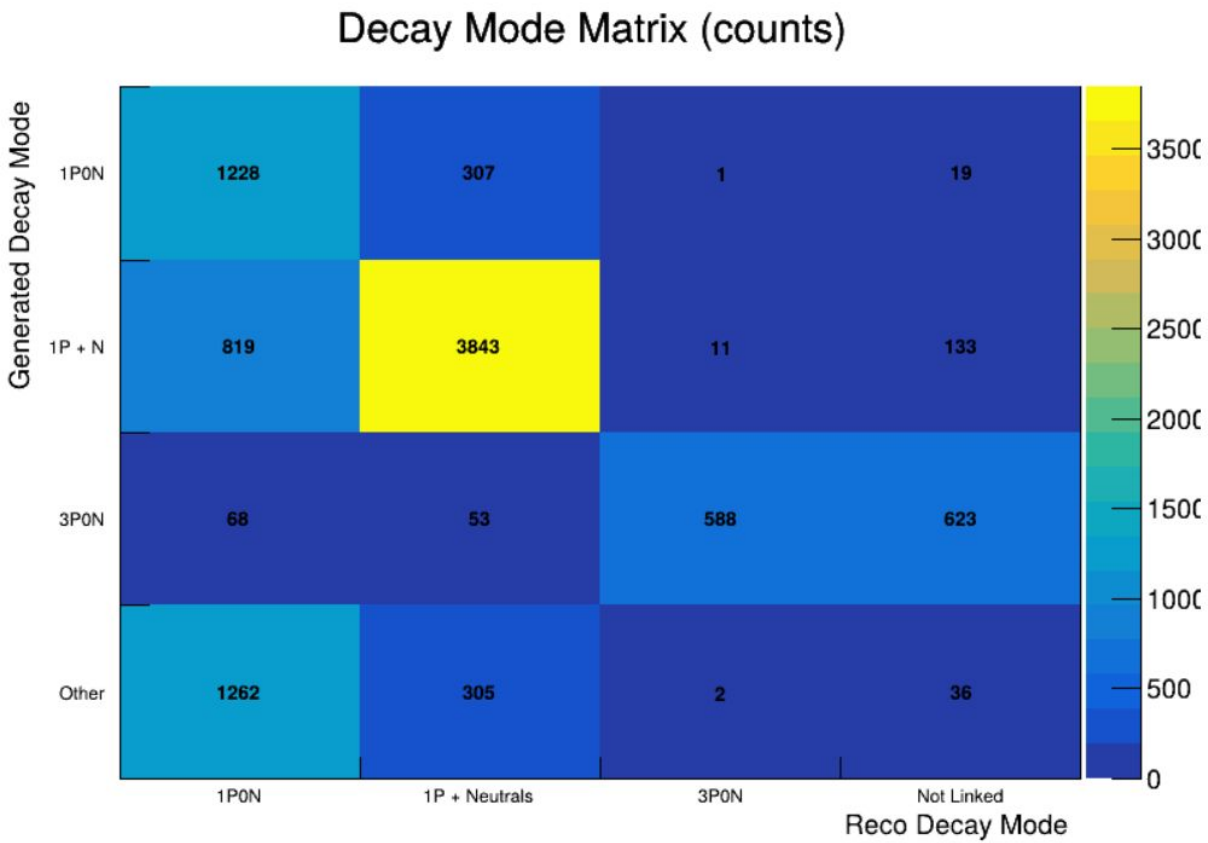
Table of Uncertainties on cross section for each canal

Canal	Cut EMF < 0.95	No EMF Cut
$\tau\tau$	1.0%	0.8%
$\tau_h\tau_h$	1.4%	1.1%
$\tau_h\tau_e$	2.2%	1.9%
$\tau_h\tau_\mu$	2.0%	1.8%
$\tau_{1\pi}\tau_{1\pi}$	2.0%	1.4%
$\tau_{1\pi}\tau_{3\pi}$	2.0%	1.7%
$\tau_{3\pi}\tau_{3\pi}$	4.3%	4.2%

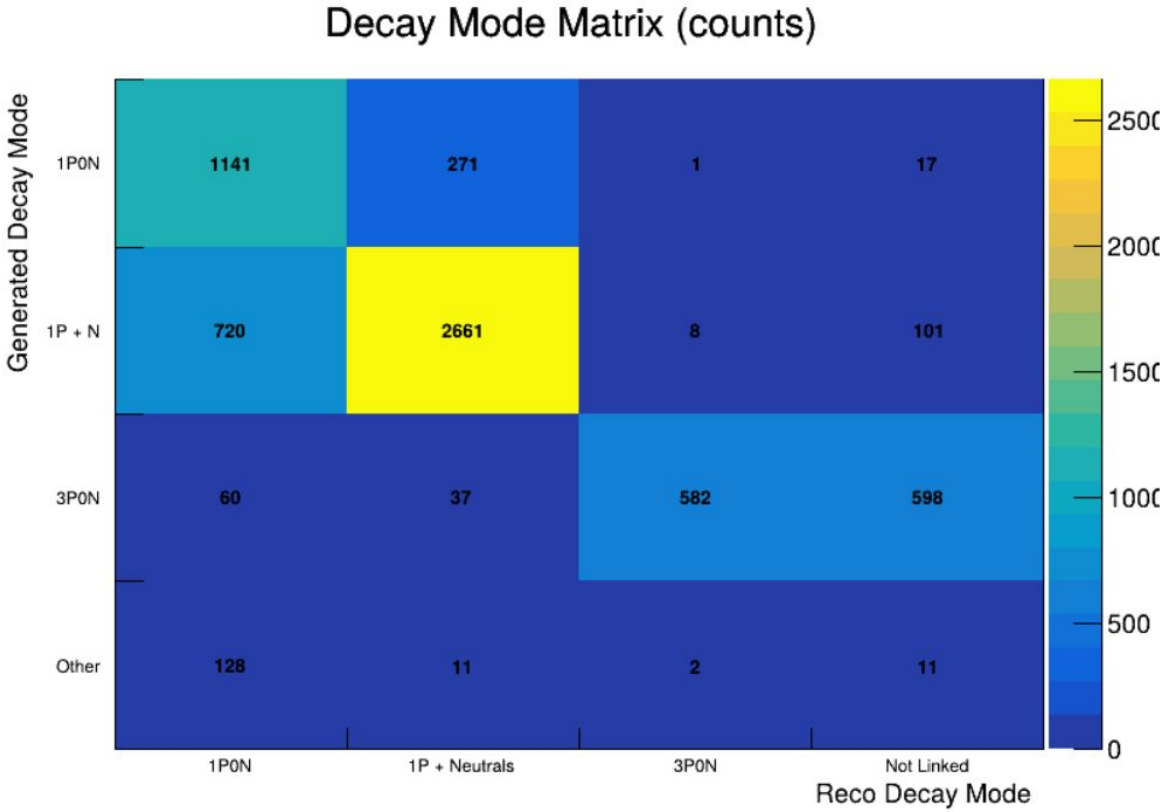
Statistical uncertainties on the cross section of H→tautau for each canal with and without EMF cut

Thank you for your attention

Tau Decay Mode classification Matrix (Taus Had)



Tau Decay Mode Matrix EMF < 0.95 (Taus Had)



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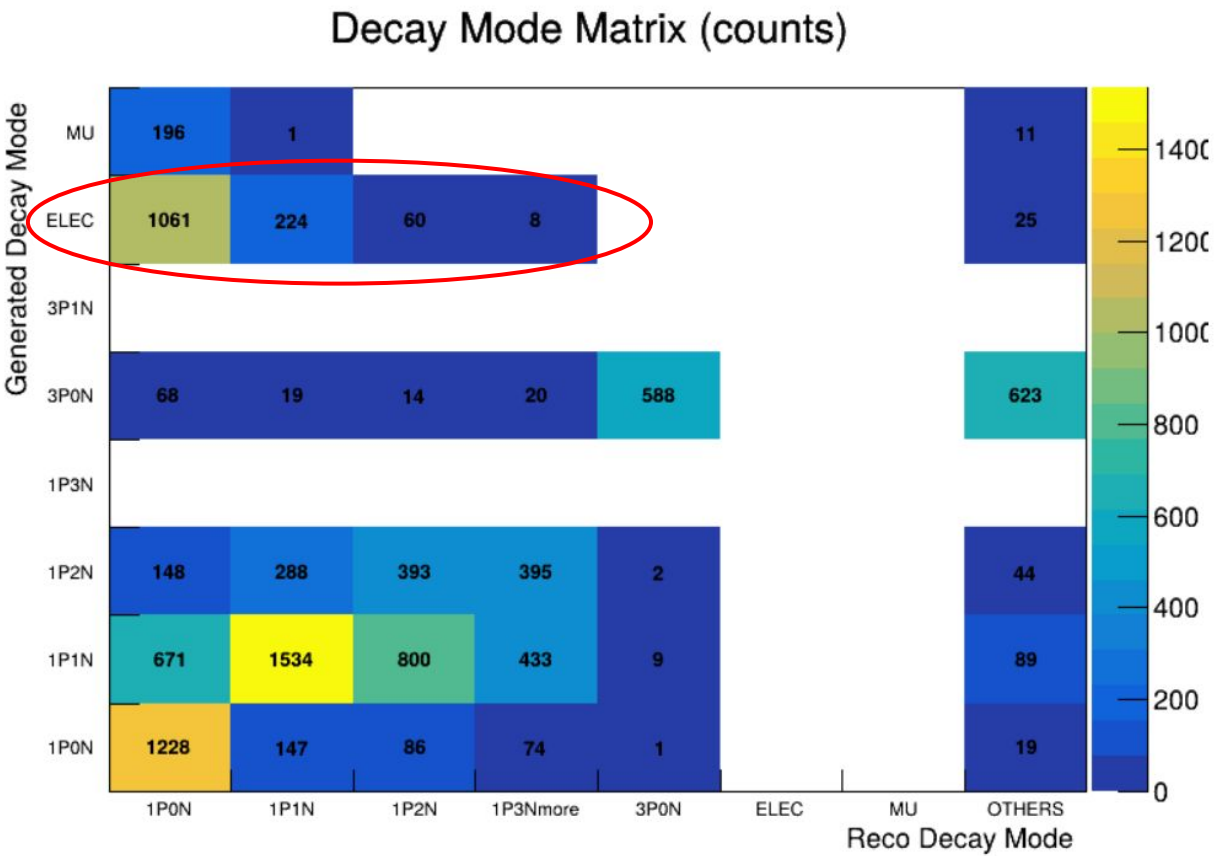

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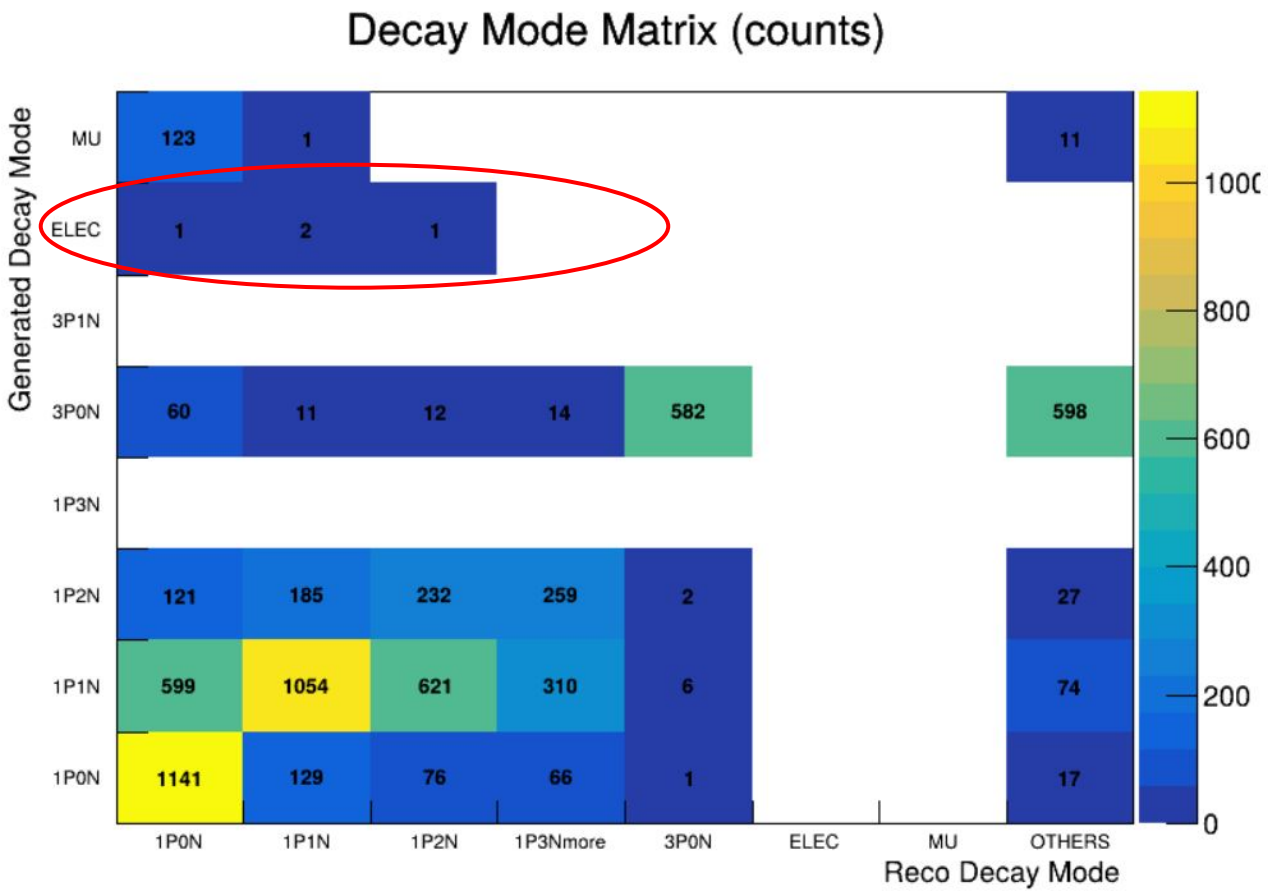
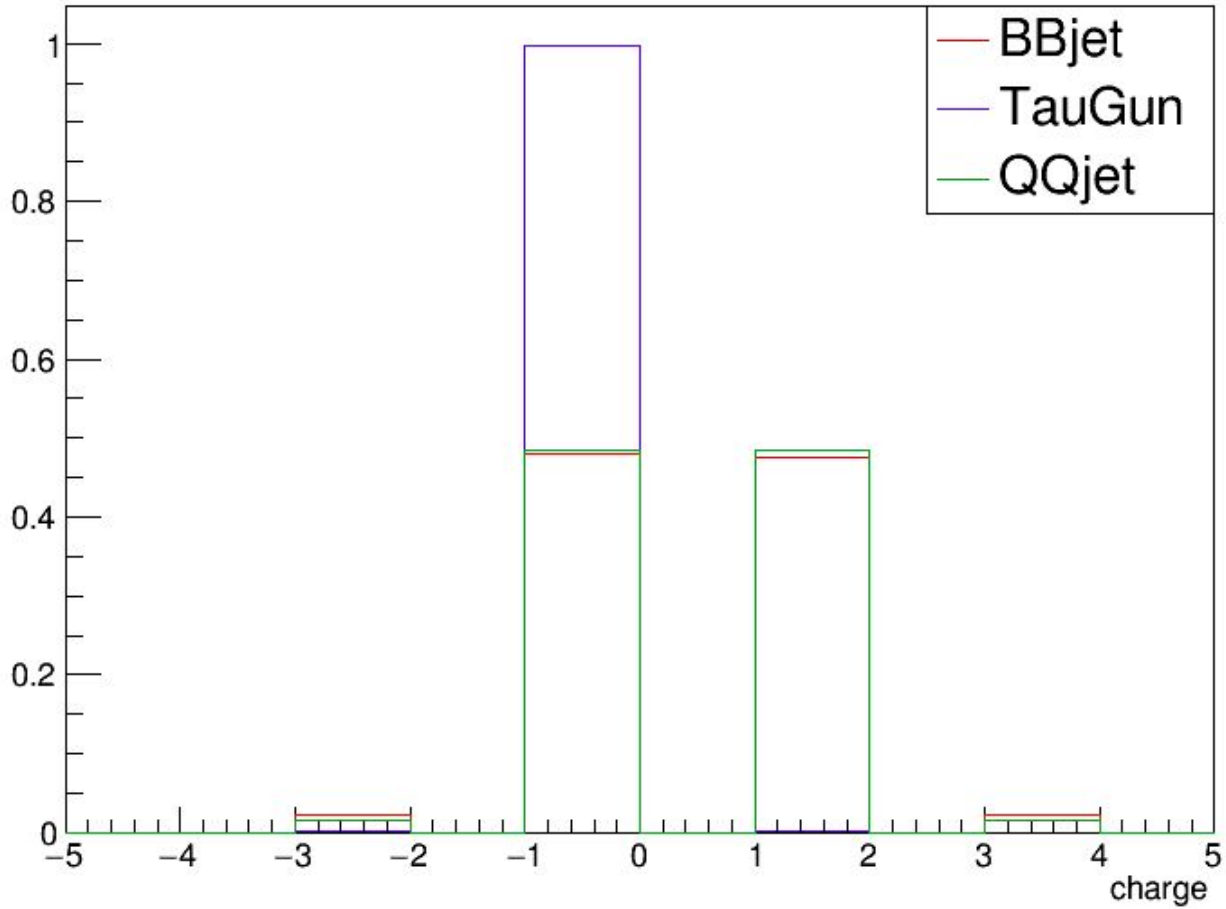
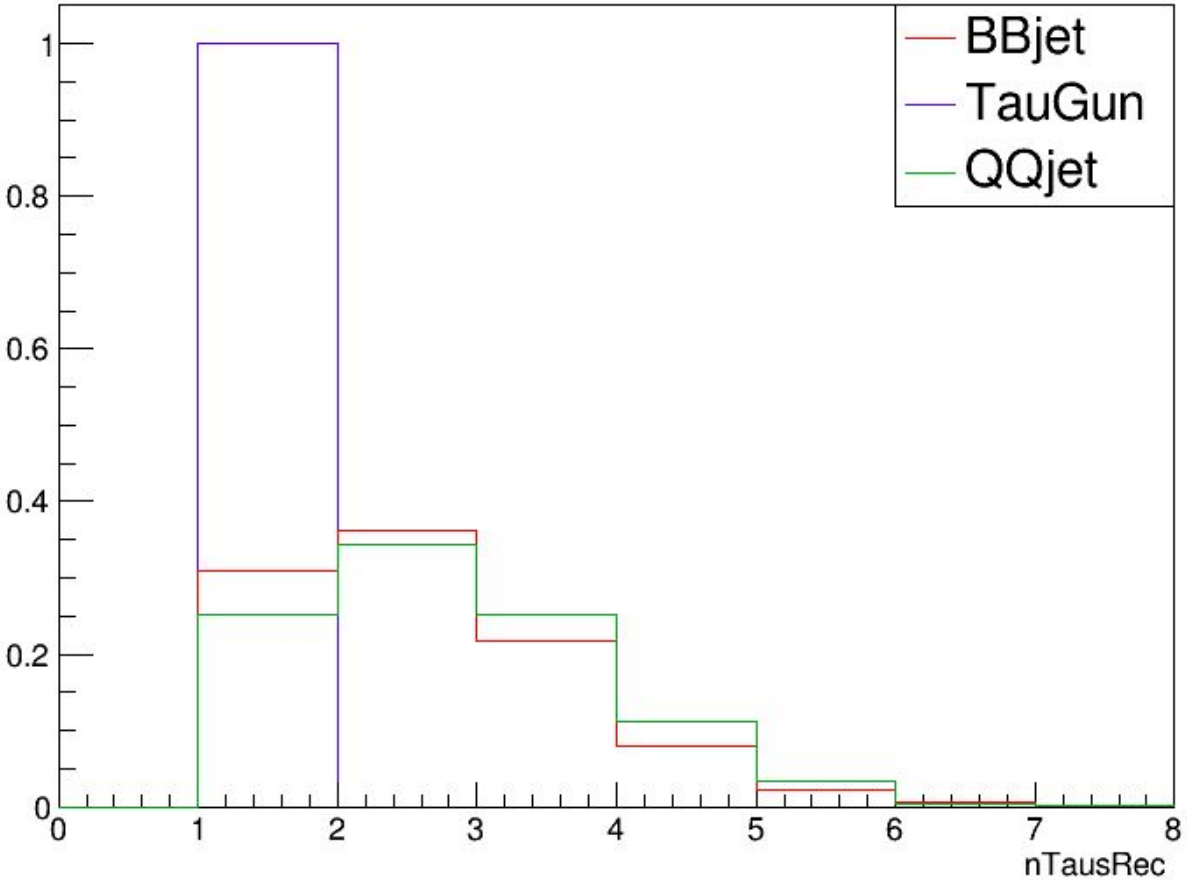


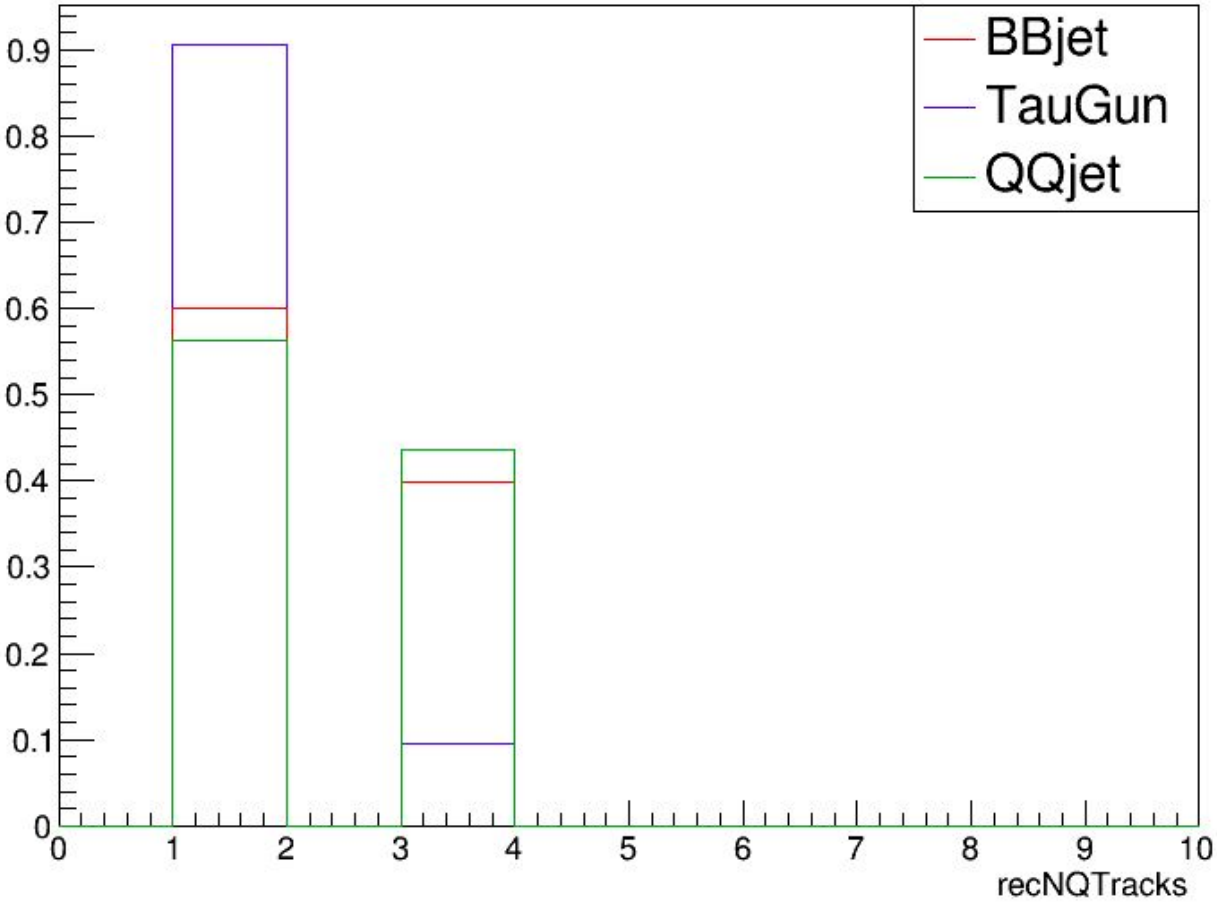
Reconstructed Charge



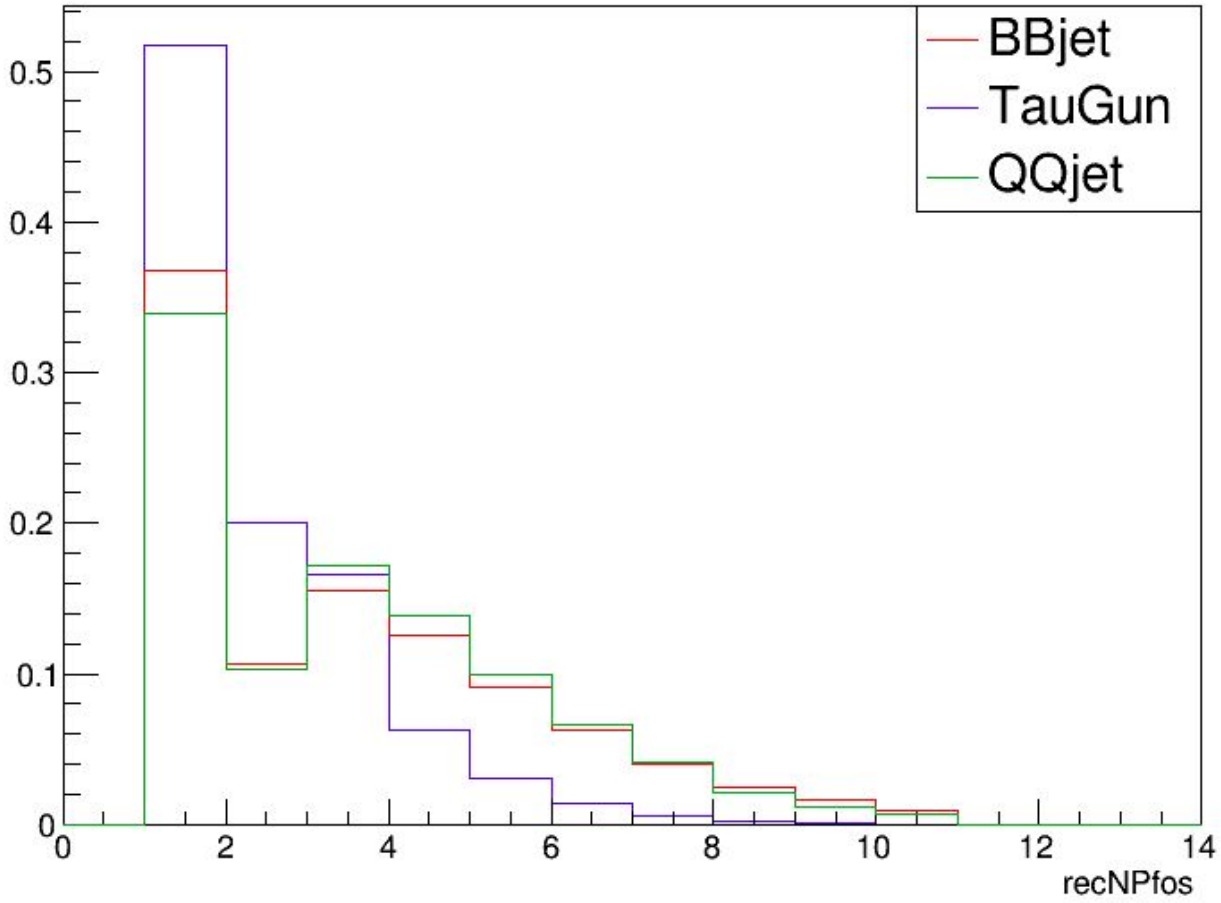
Number of Reconstructed Taus



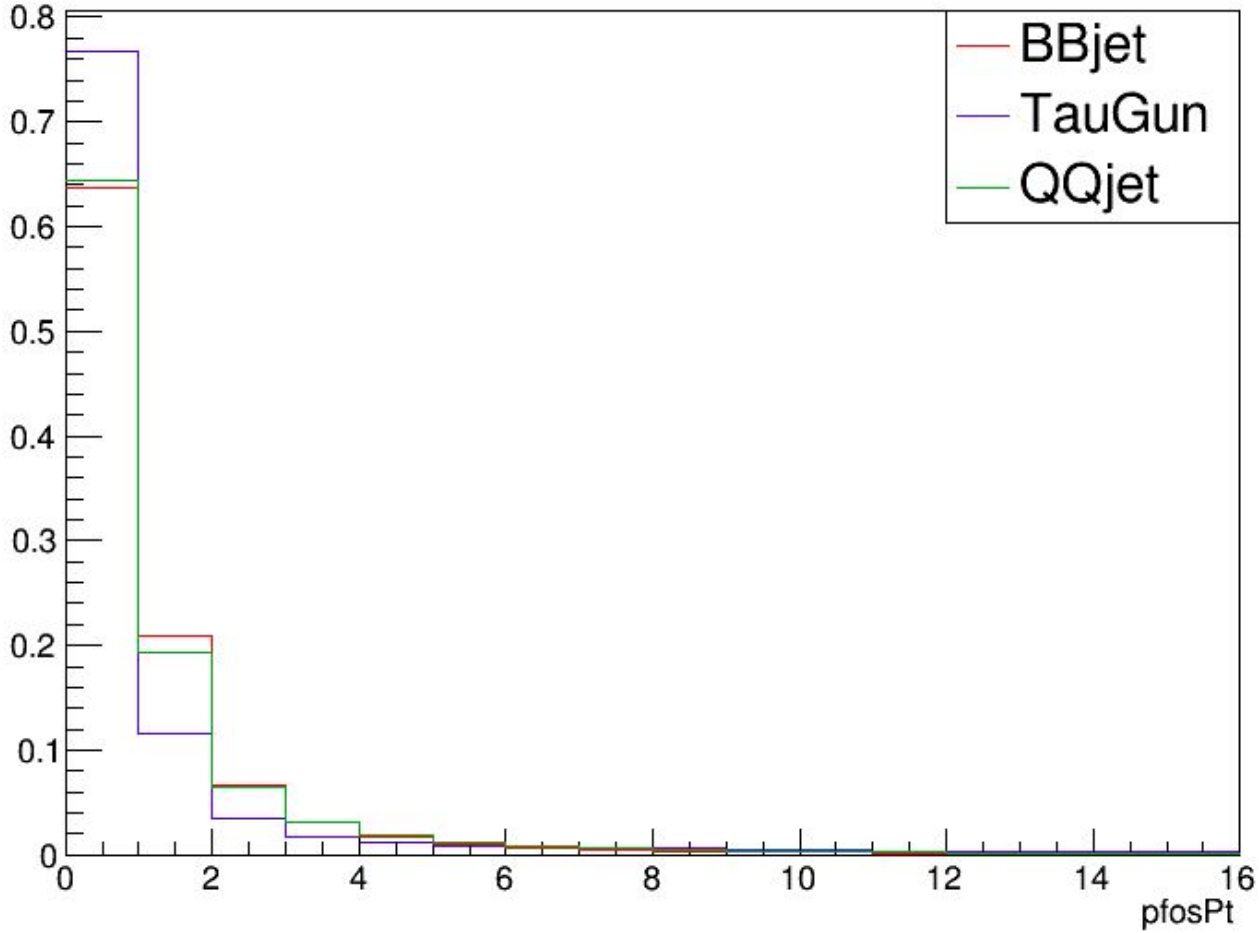
RecNQTracks



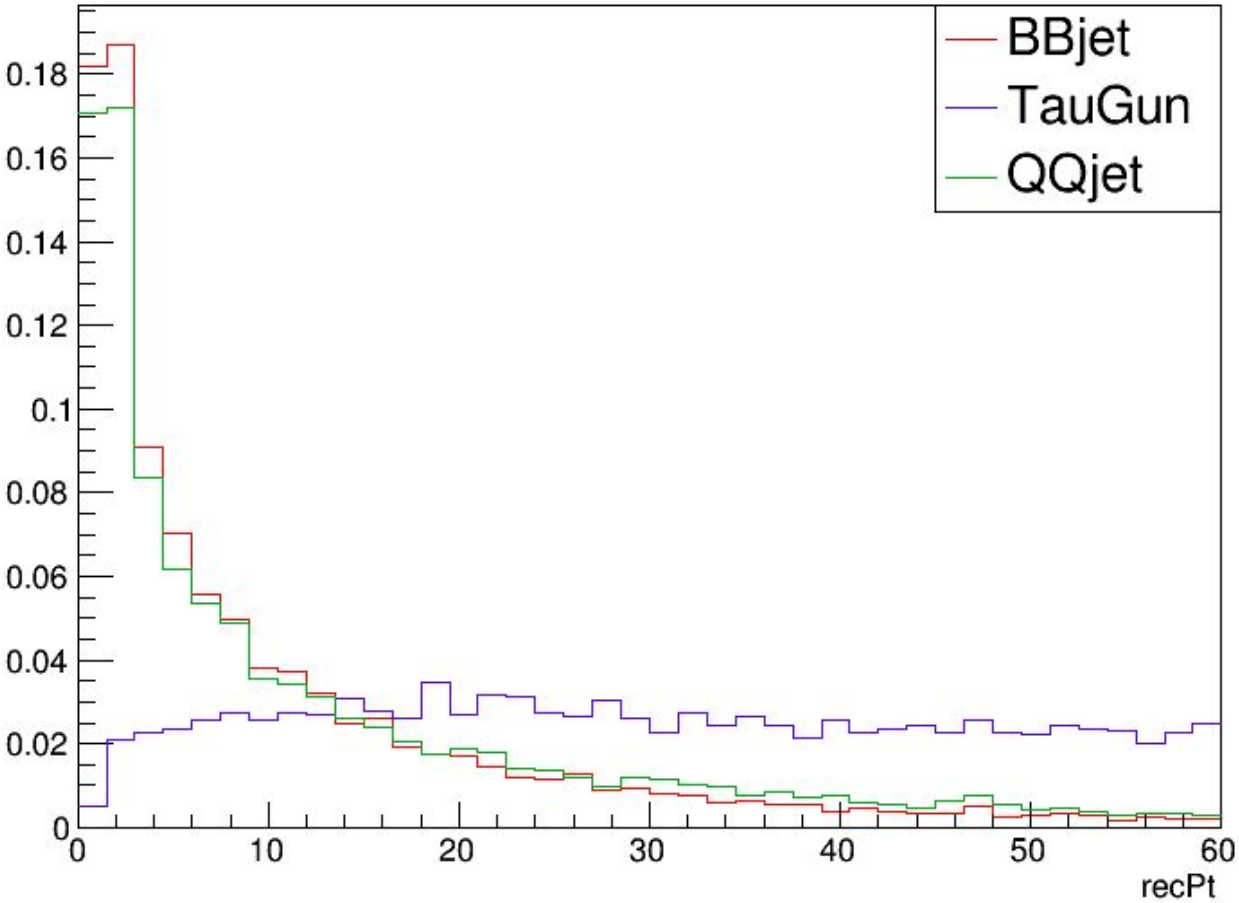
Number of reconstructed Pfos



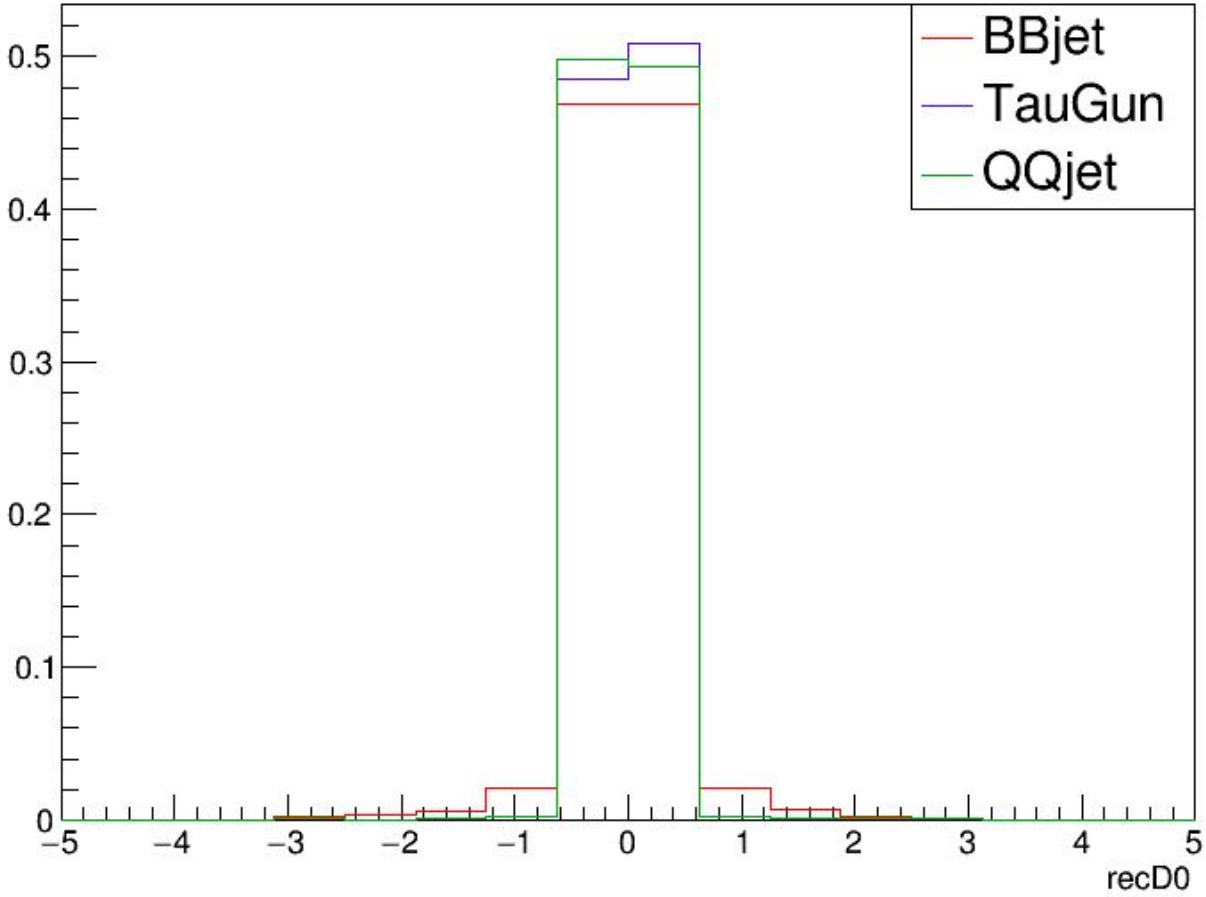
Pt Pfos


BBjet
TauGun
QQjet
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
8
10
12
14
16
pfosPt

Reconstructed tau Pt



D0



Reconstructed Seed Energy