Lepton Universality test in $t\bar{t} \rightarrow b\bar{b}l\tau$ decays

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LIP

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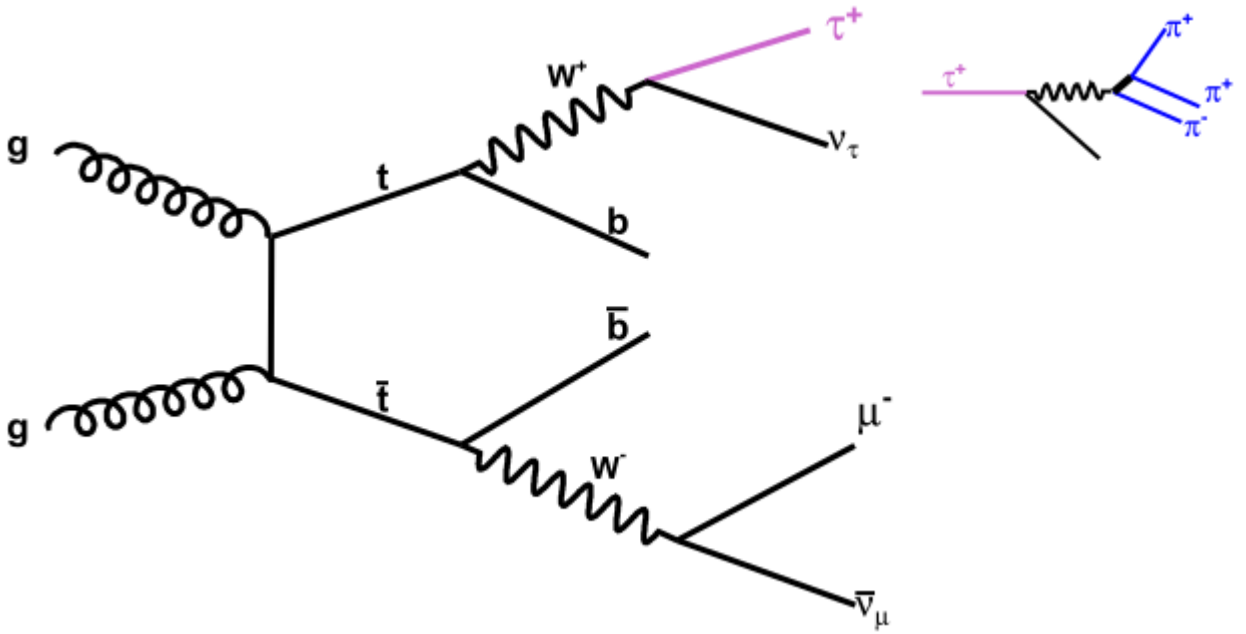
Project Overview

- time frame: 2 weeks plus 1 week of general tutorials
- participants: Joana Vital (1st year) and Jose Neves (2nd year)
- physics interest: the test of Lepton Universality in the W boson decays in $t\bar{t}$ pairs produced at LHC, ratio of $BR(W \to \tau\nu_\tau / BR(W \to \ell\nu_\ell)$
- the goal of the project: using simulated events of CMS detector study the possibilities to purify the $t\bar{t} \to \ell\tau$ selection and consider the uncertainties in the measurement of the ratio $t\bar{t} \to \ell\tau / t\bar{t} \to \ell\ell$ which leads to $BR(W \to \tau\nu_\tau / BR(W \to \ell\nu_\ell)$
- the project consisted of 4 topics with prospect to purify the event selection:
  - the kinematics of jets in the main background process $t\bar{t} \to b\bar{b}\ell q\bar{q}$
  - symmetry of the contribution of b quarks to the fake tau background
  - Secondary Vertex of tau decaying to 3 charged particles
  - Dalitz parameters of such tau decays
- additional topics: the effects of statistical and systematic uncertainties, cancellation of systematic uncertainties in ratio measurements, dependence of systematic identification uncertainty on the kinematics of the tau etc.

Top quark pair decay into tau lepton



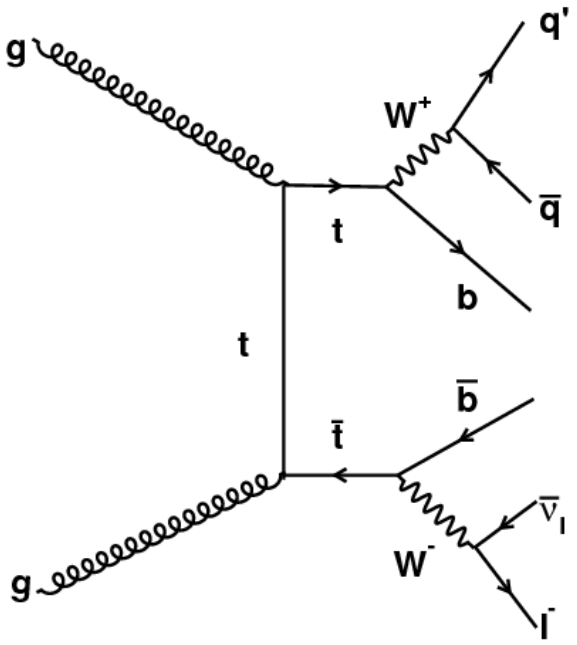
Event Selection

- In detector we are looking to detect:
  - Muon/eletron signatures
  - 3 jets(at least one b-tagged, another one identified as tau)
  - Particles with large transverse momentum
- However:
  - Specific background(misidentified taus)
  - Large uncertainty of tau identification

Background

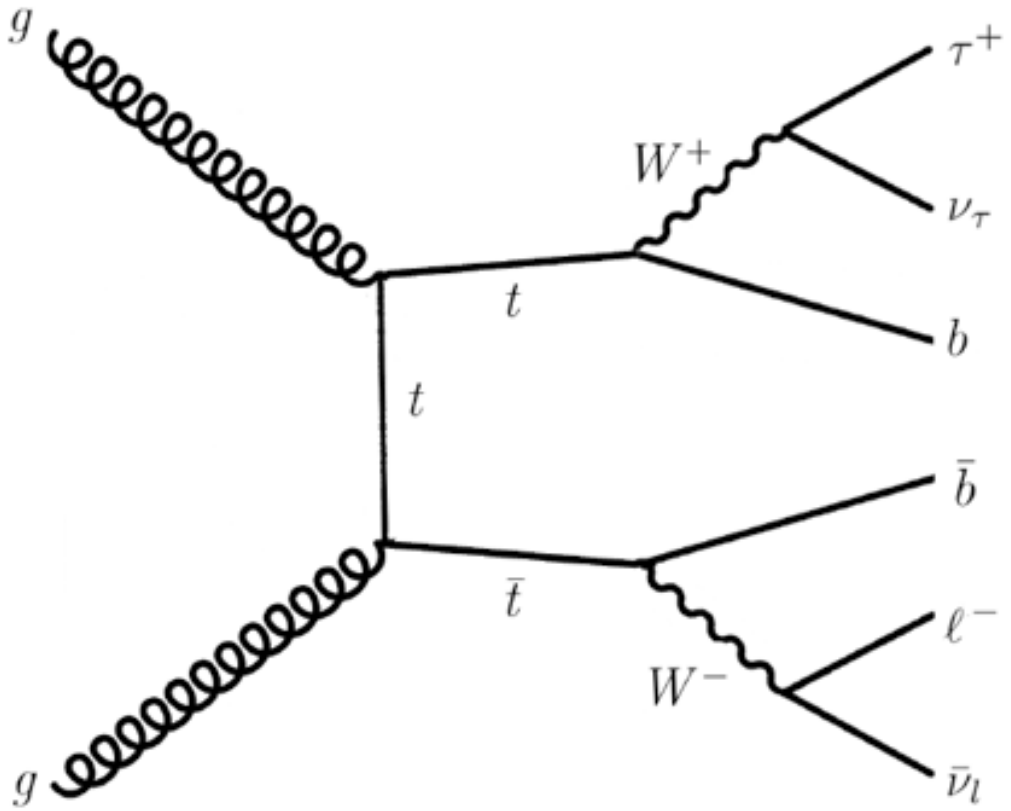
- Background due to misidentified eletrons and muons. (negligenciable)

- Background due to misidentified tau jets.



Background due to misidentified tau jets

- The first thing we tried to do was using the kinematics of the decay products to see if they belonged to the channel of the signal.
- (mass(W)=80GeV, mass(tau)=1.776Gev,mass(neutrino)=0GeV)



Background due to misidentified tau jets

- We do the sum of all registered hadronic jets and sum it with the b-tagged jets to see if it gives as the mass of top quark like the code bellow shows:

```
if event.gen_proc_id in (31,32):
        histo_sig.Fill(event.event_taus[0].pt())
        for i1, j1 in enumerate(event.event_jets_r):
            for j2 in event.event_jets_r[i1+1:]:
              hist_pair_sig.Fill((j1+j2).mass())
              for bjet in event.event_jets_b:
                hist_trio_sig.Fill((j1+j2+bjet).mass())
                hist_trio_2D_sig.Fill((j1+j2+bjet).mass(),(j1+j2).mass())
elif 20<event.gen_proc_id<25:
       histo_bck.Fill(event.event_taus[0].pt())
       for i1, j1 in enumerate(event.event_jets_r):
            for j2 in event.event_jets_r[i1+1:]:
              hist_pair_bck.Fill((j1+j2).mass())
              for bjet in event.event_jets_b:
                 hist_trio_bck.Fill((j1+j2+bjet).mass())
                 hist_trio_2D_bck.Fill((j1+j2+bjet).mass(),(j1+j2).mass())
```

Background due to misidentified tau jets

- Results for signal:

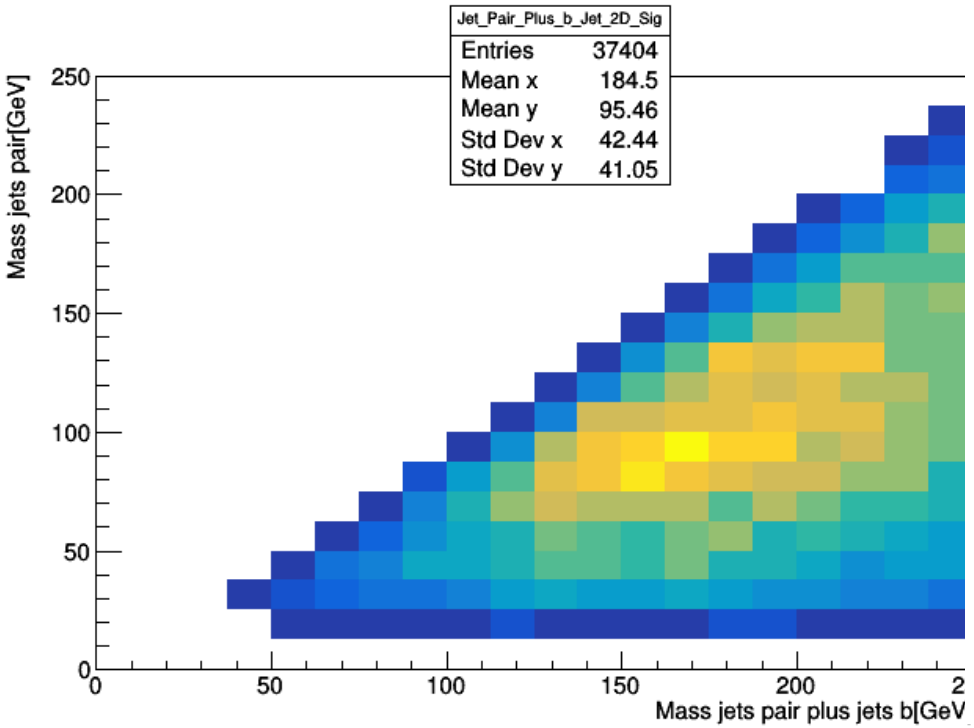


Fig: Dalitz diagram for top quark mass(Signal)

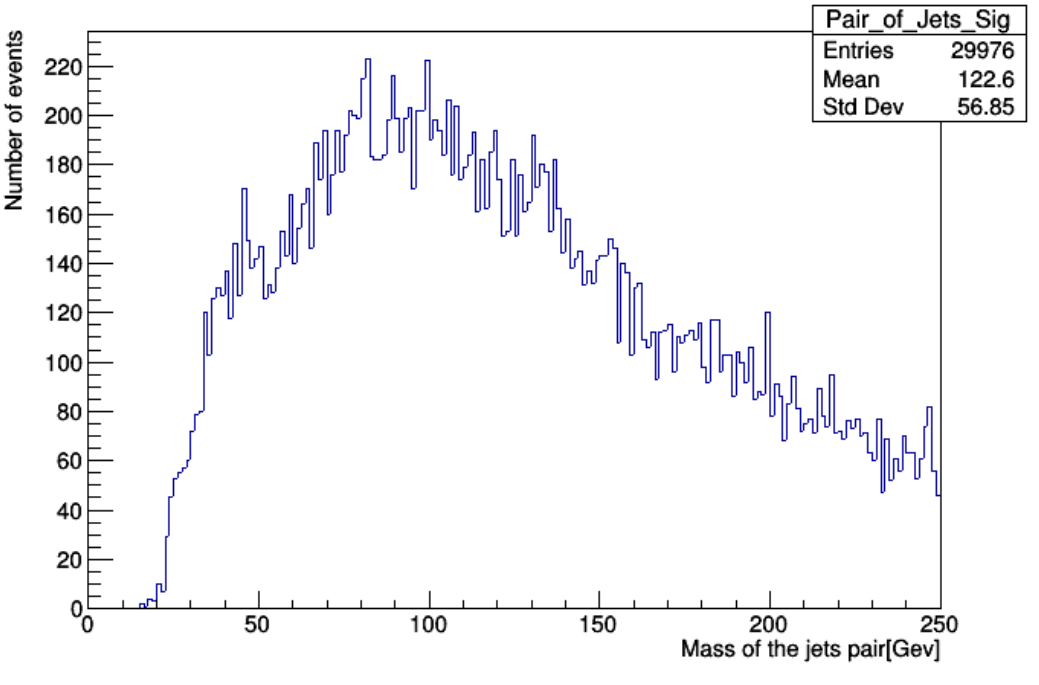


Fig:Distribution of the number of events for tau pt values

Background due to misidentified tau jets

- Results for background:

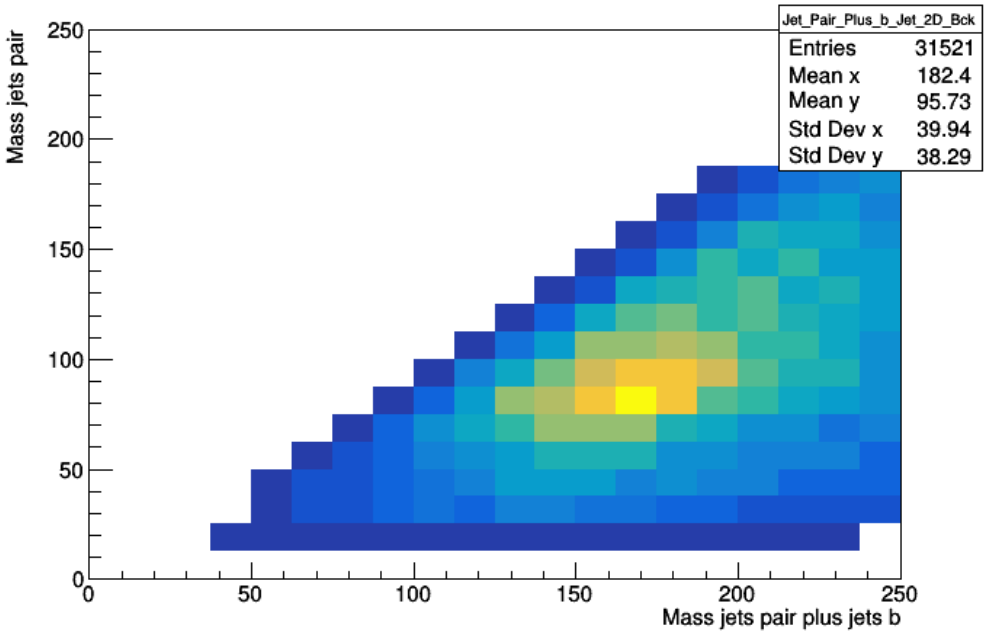


Fig: Dalitz diagram for top quark mass(Signal)

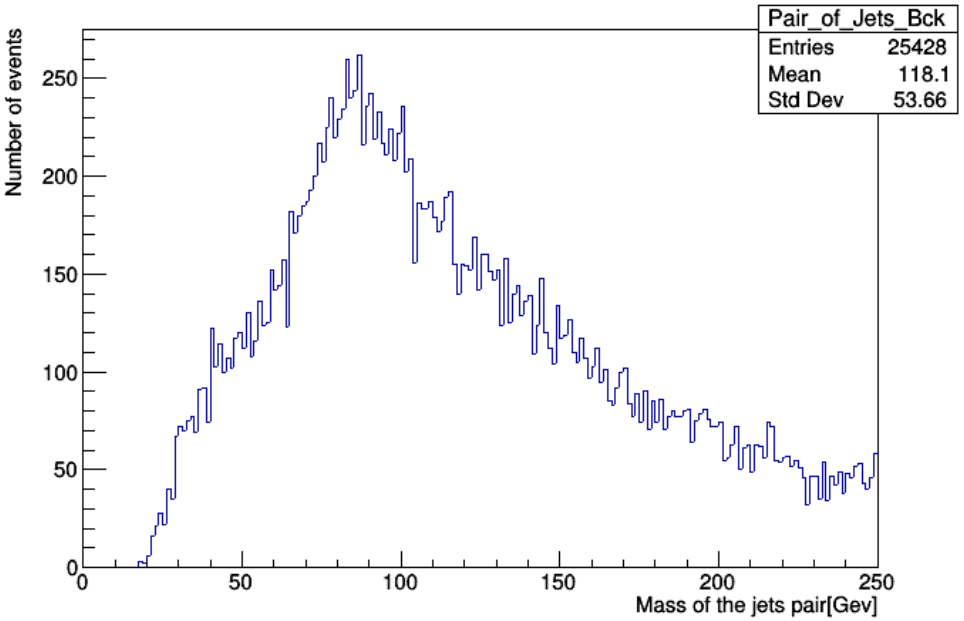


Fig:Distribution of the number of events for tau pt values

Background due to misidentified tau jets

- The method can select the jets that came from tau.
- It is, however, ineficient because of the large amount of jets to sum.
- Besides, we can’t get a clean distintion between signal and background.

Background due to misidentified tau jets

- What if we could separate misidentified tau jets by it's origin?

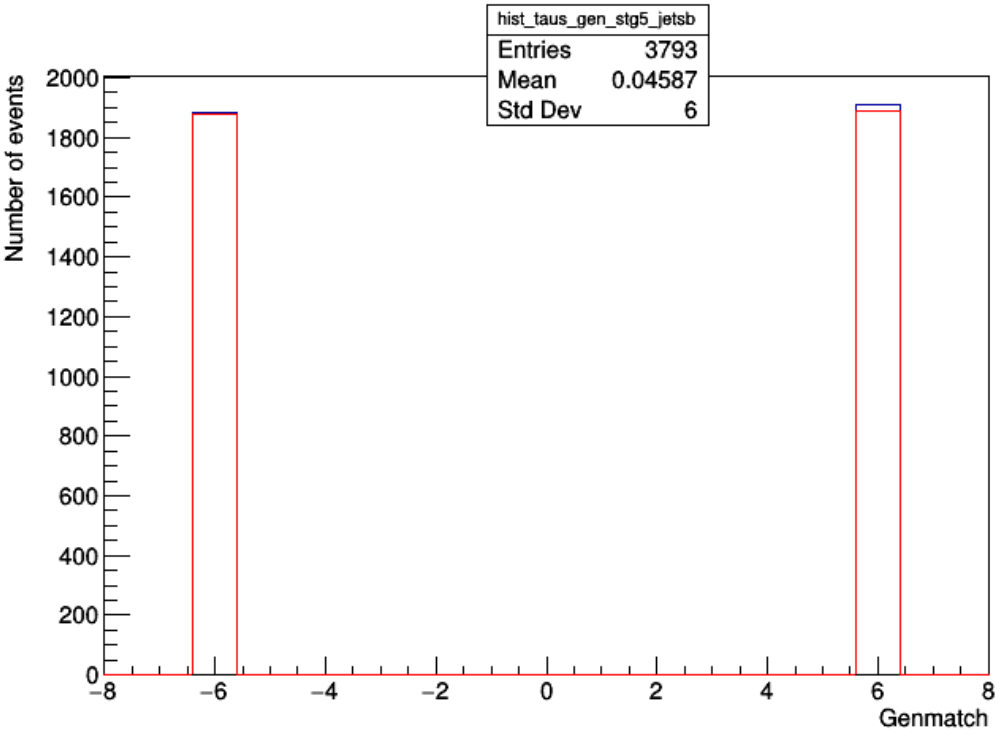


Fig: Genmatch for fake taus coming from b jets

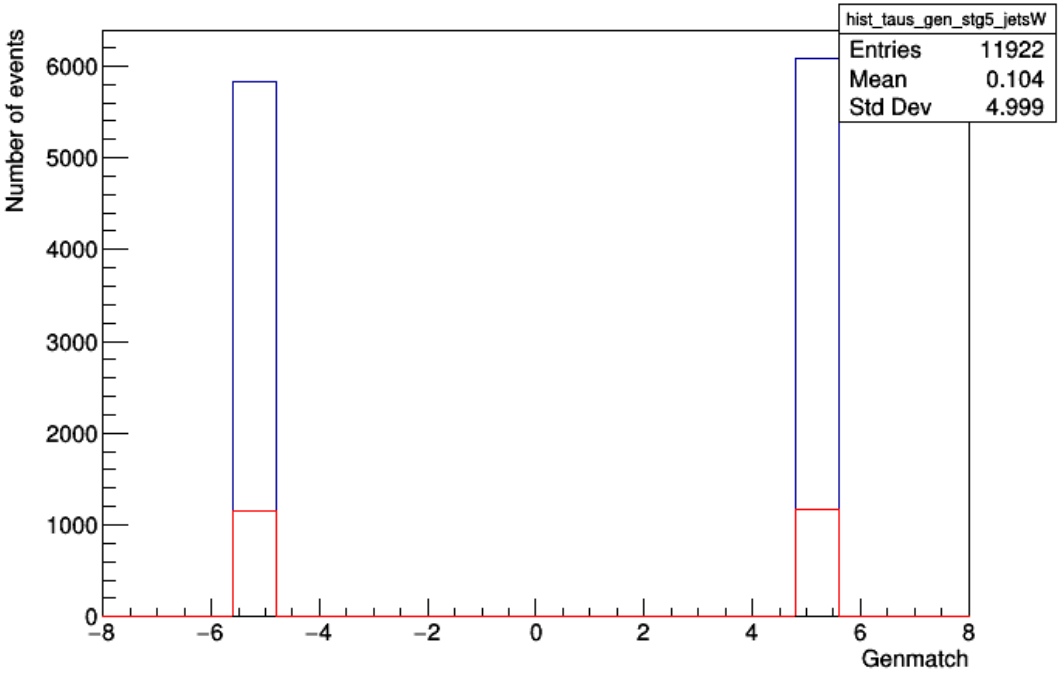


Fig: Genmatch for fake taus coming from W jets

Background due to misidentified tau jets

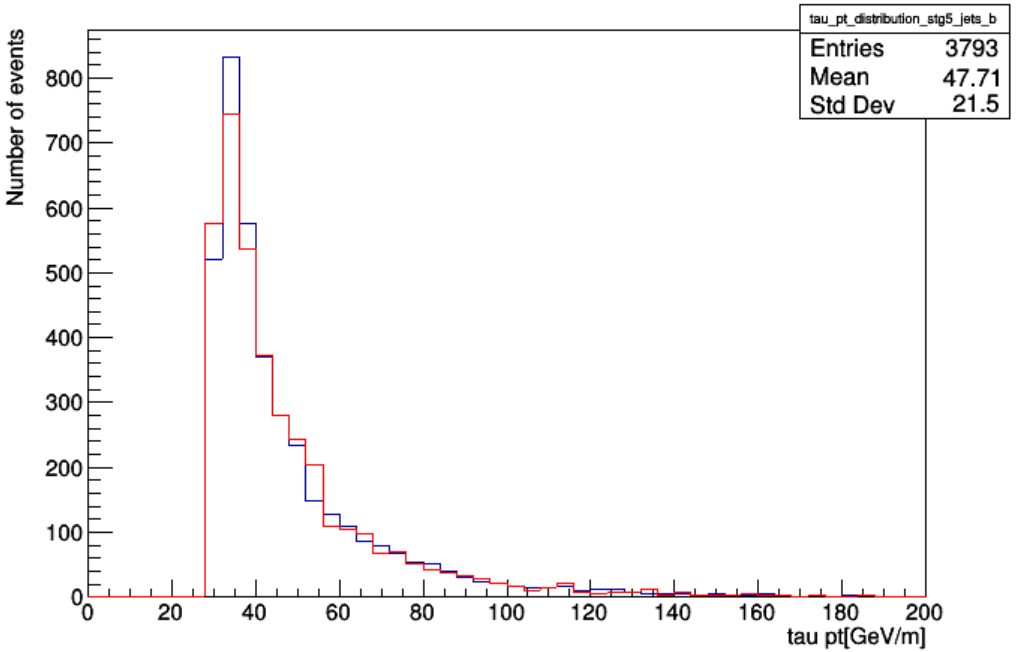


Fig:tau pt distribution for OS and SS for b fakes

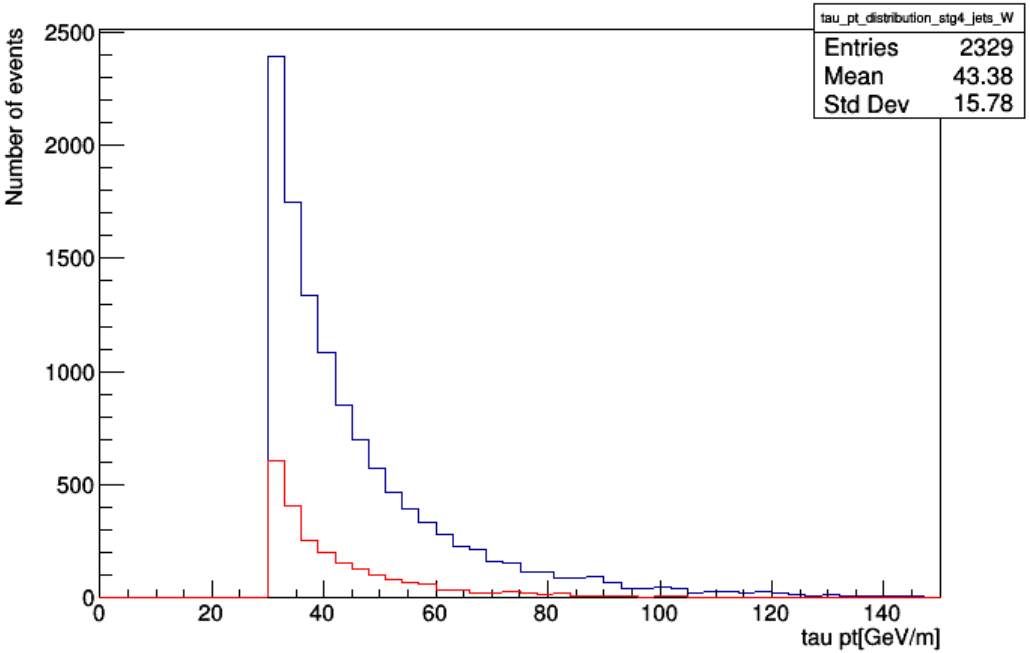


Fig:tau pt distribution for OS and SS for W fakes

Background due to misidentified tau jets

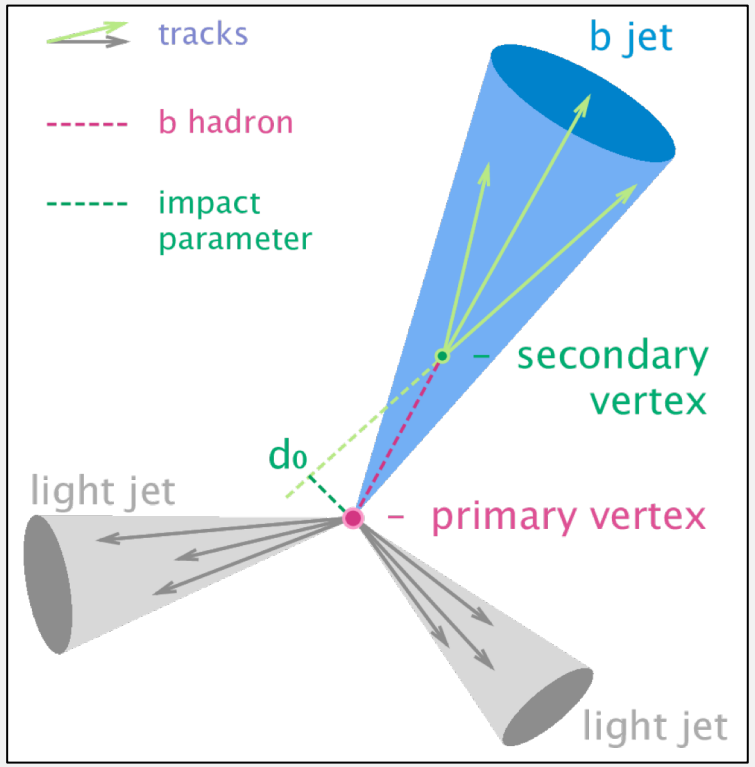
- We verify that for fake taus coming from the b quarks of the reaction the pt distribution is the same, what confirms our hypothesis.
- We conclude that fake taus originated from b produce the same contribution in opposite signand same sign selection and can be used to constrain the background from b jets.
- What about W bosons?

HOW TO IMPROVE THE DISCRIMINATION BETWEEN TRUE TAUS AND FAKE TAUS

SECONDARY VERTICE

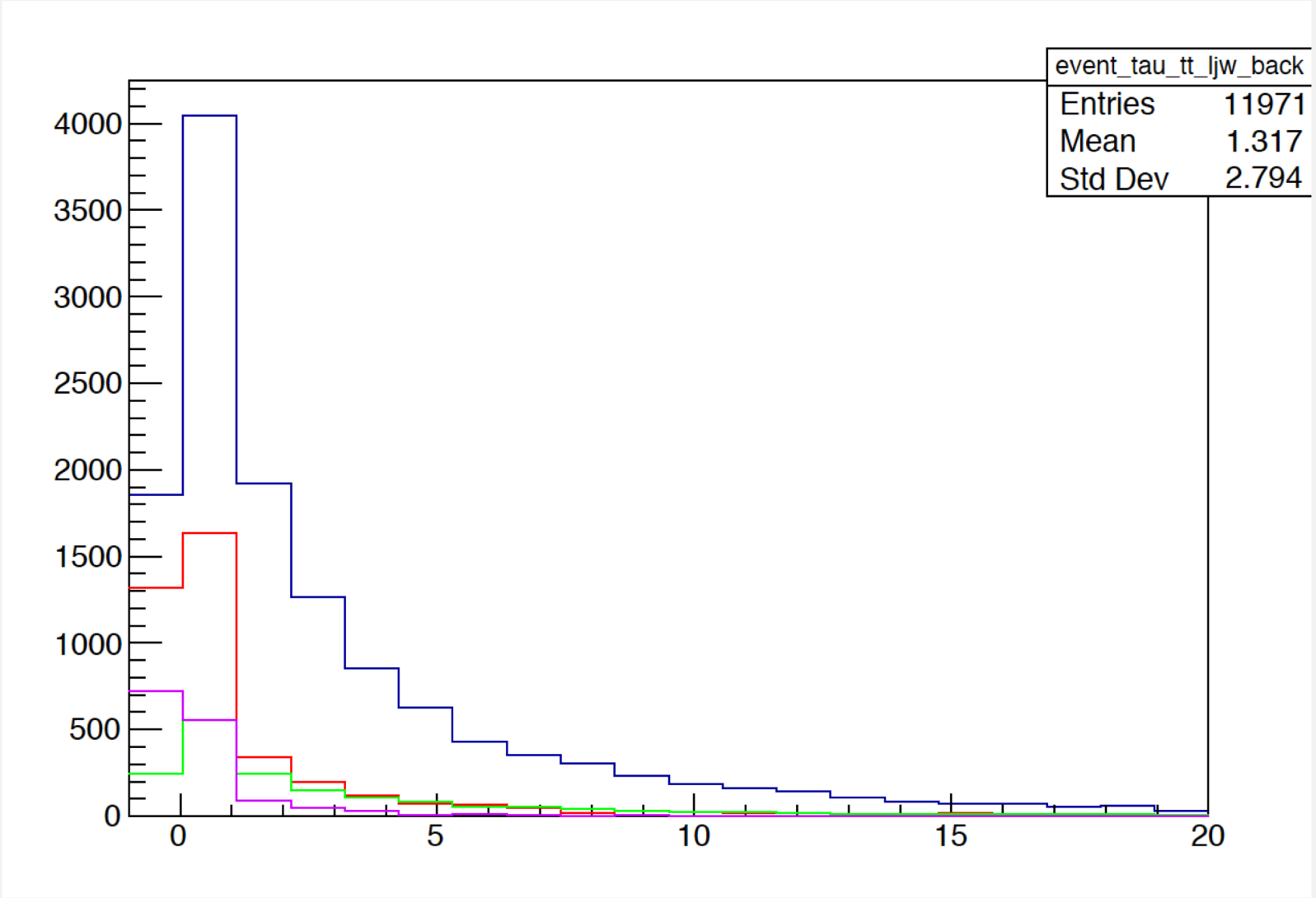
What should be expected:

- Discriminate true taus from fakes taus
- b should be the only that has some significance

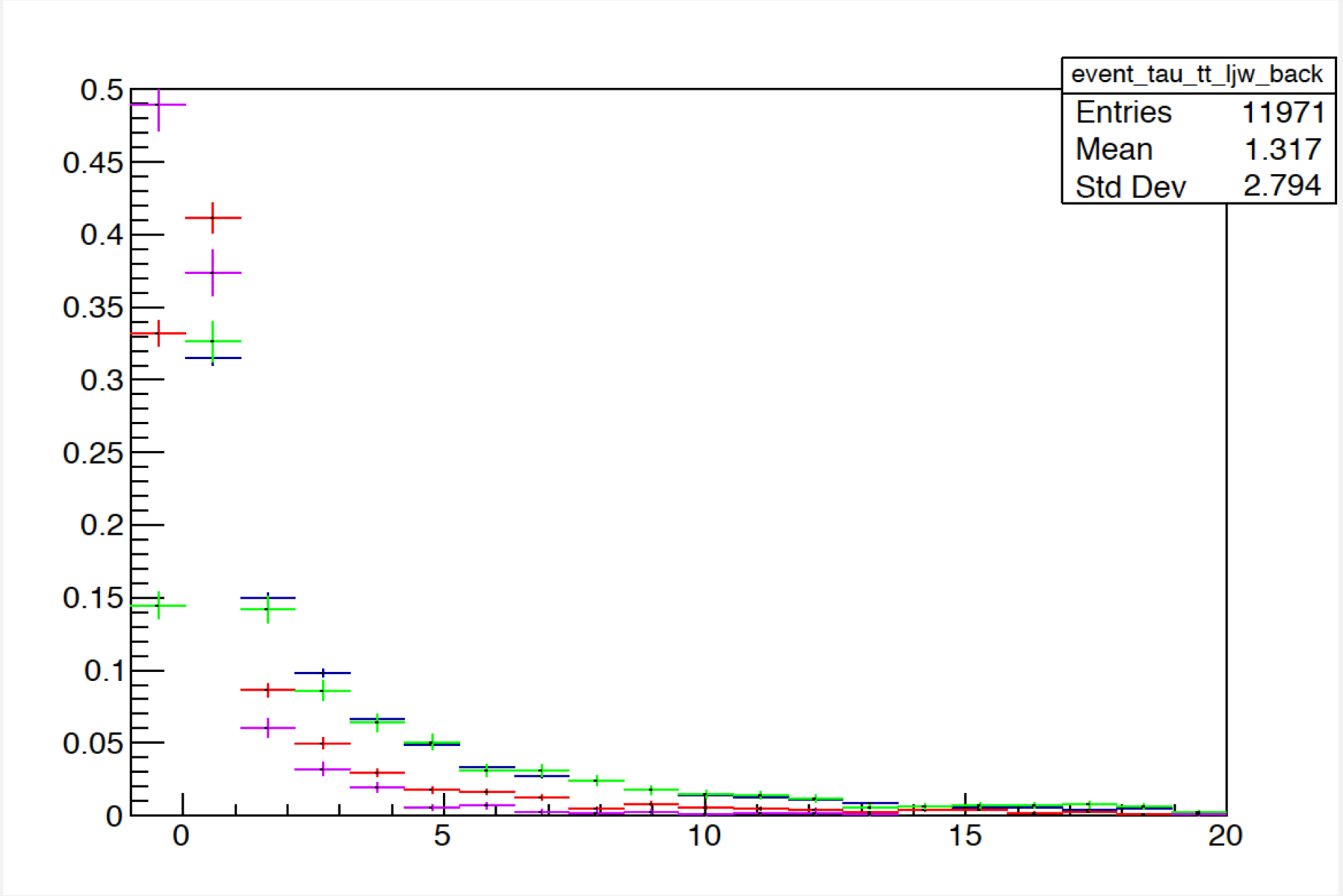


SECOND VERTICE SIGNIFICANCE

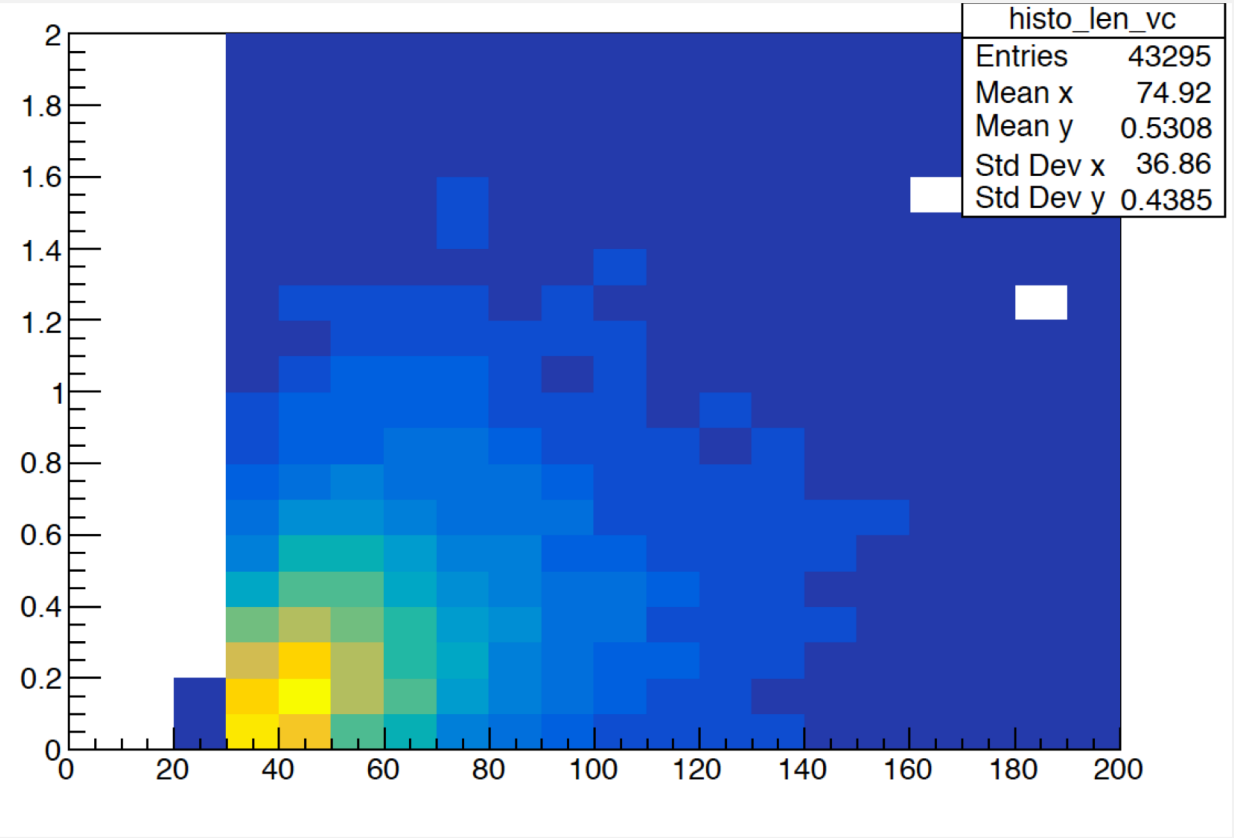
$$significance = \frac{lenght}{uncertainity}$$



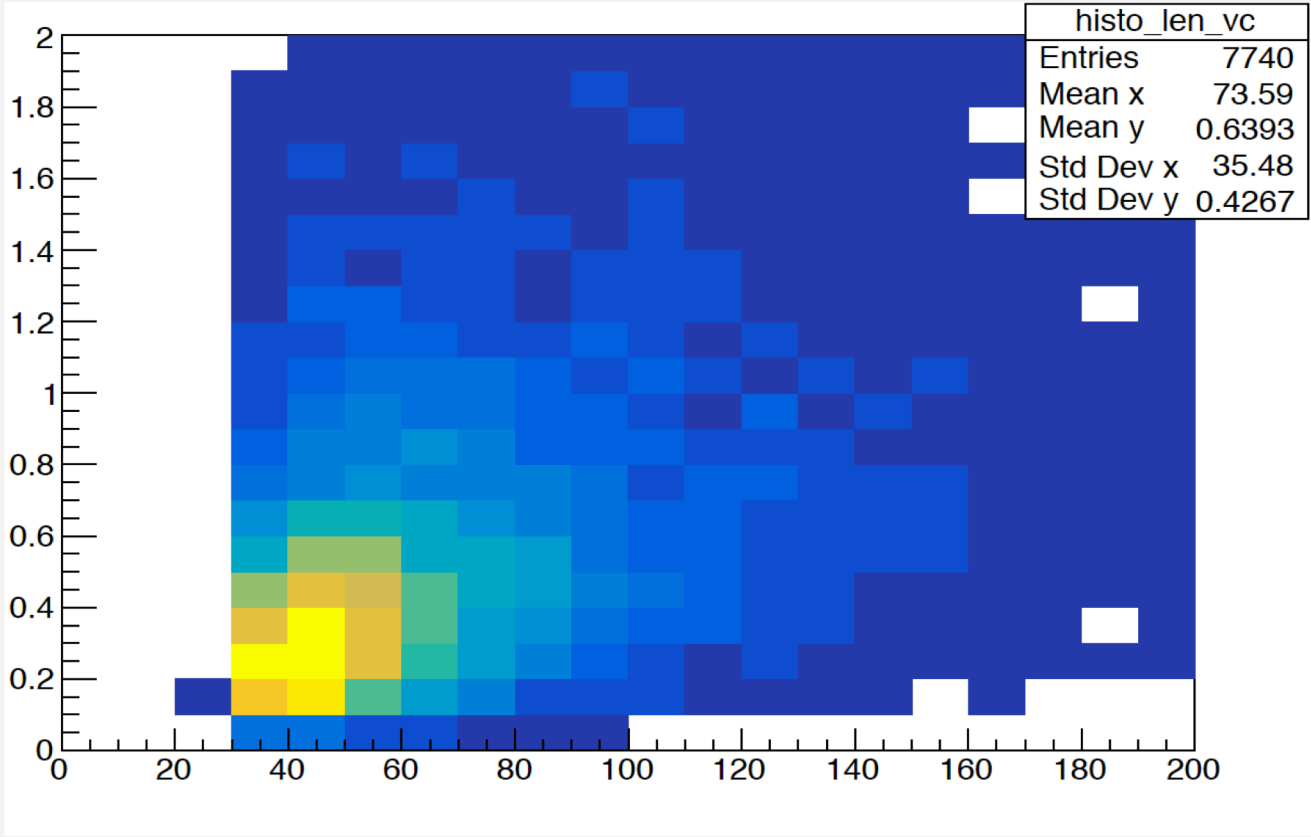
SV SIGNIFICANCE NORMALISED



CORRELATION BETWEEN THE ENERGY AND THE LENGTH OF FLIGHT

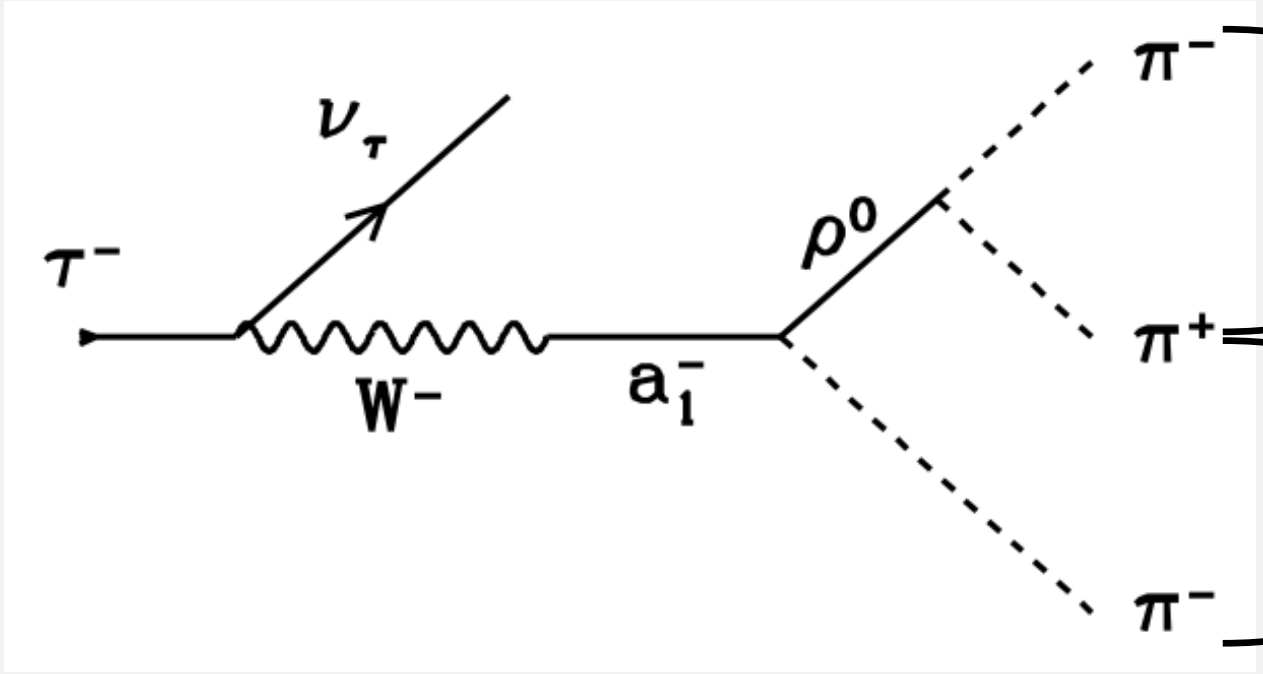


All taus

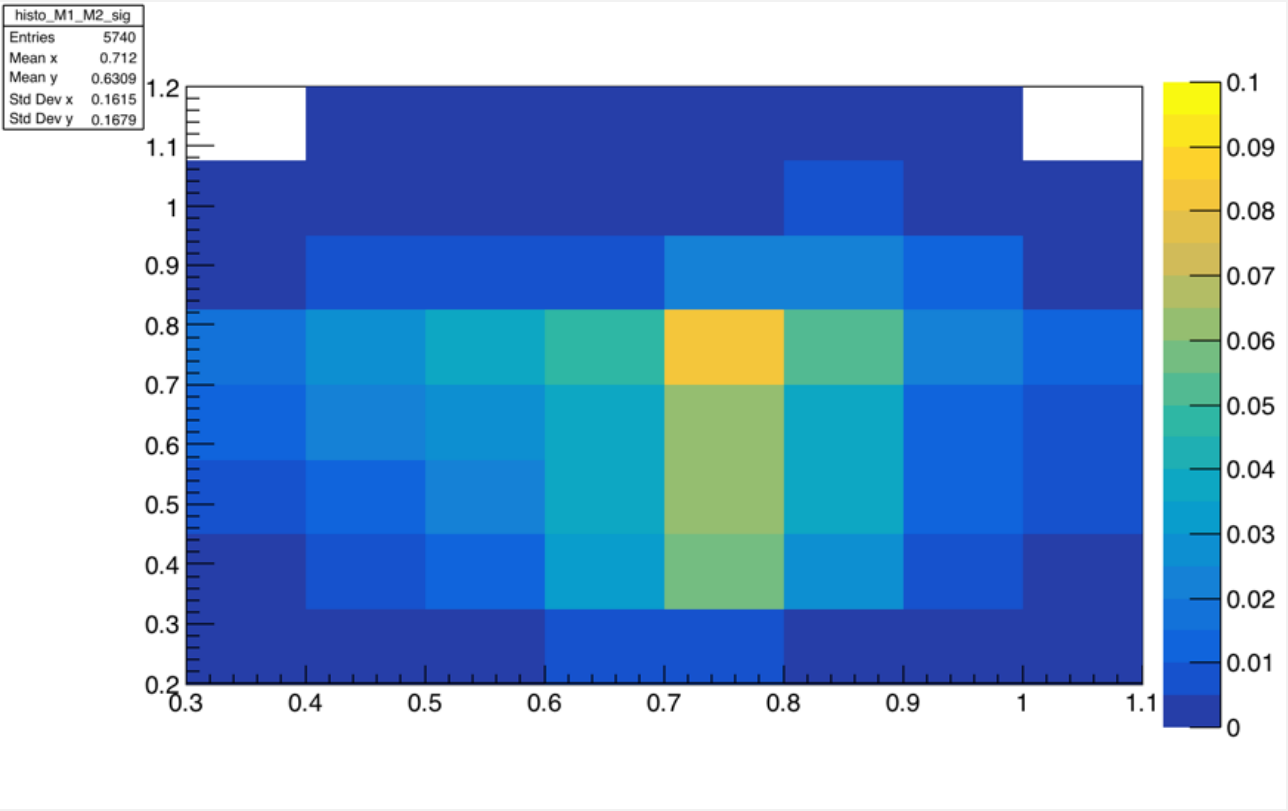


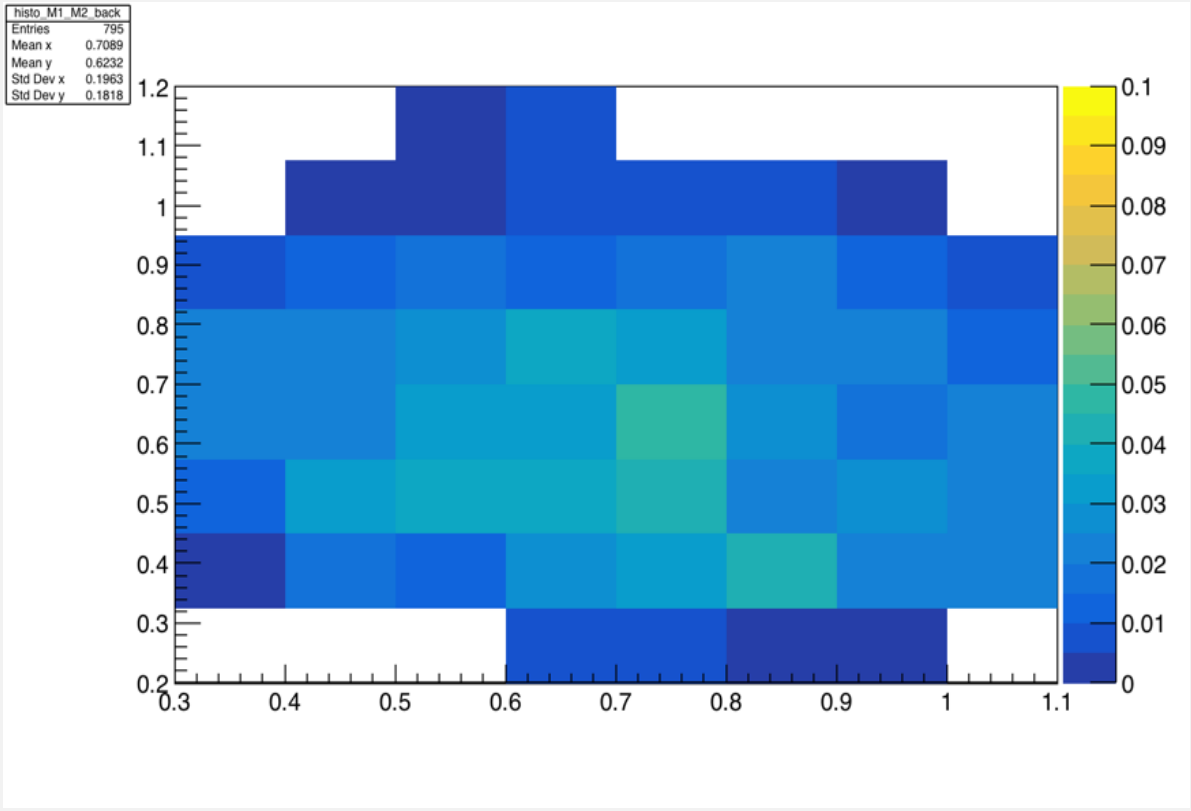
Taus with sv > 1

DALITZ PARAMETERS



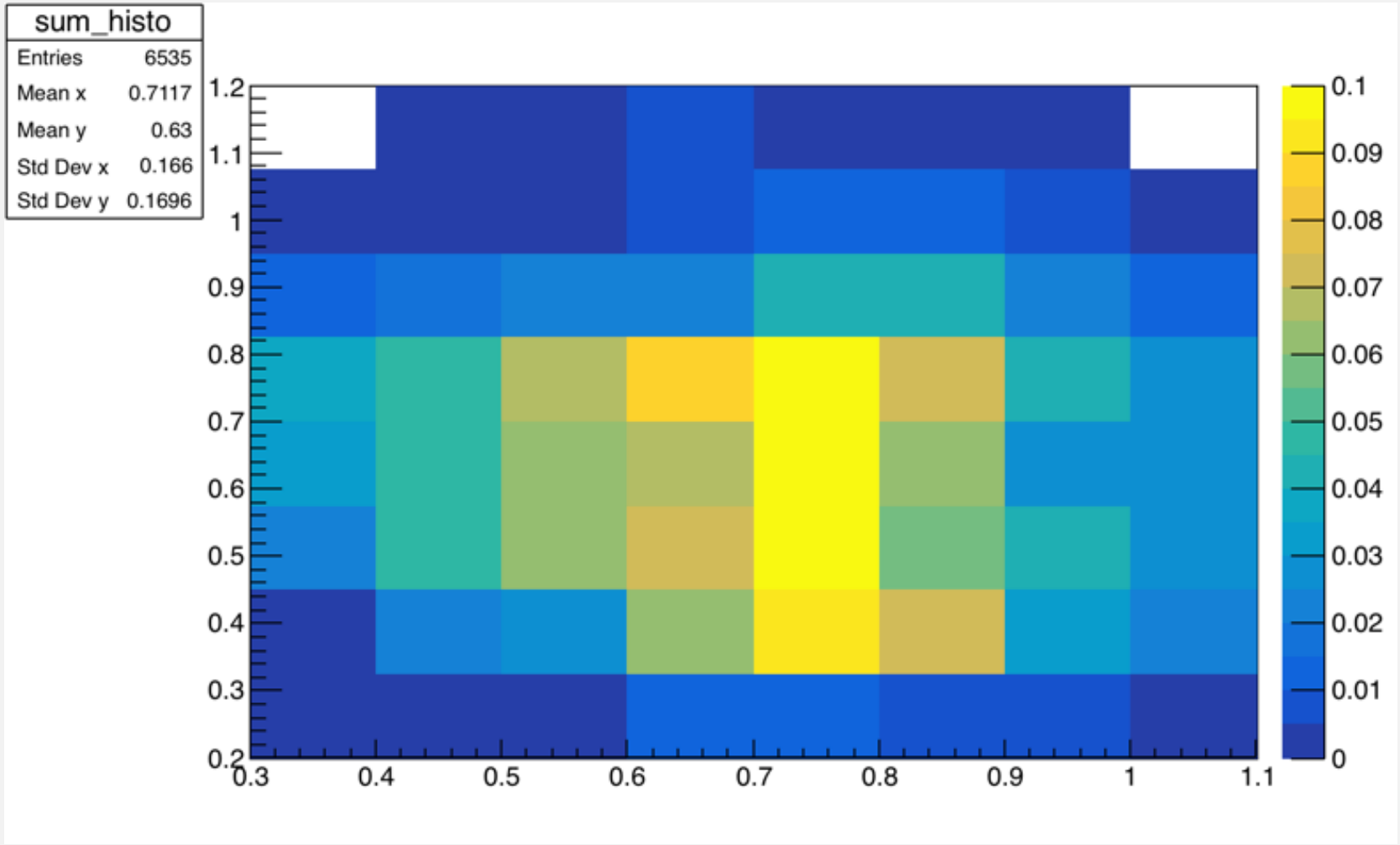
NORMALISED SIGNAL VS BACKGROUND





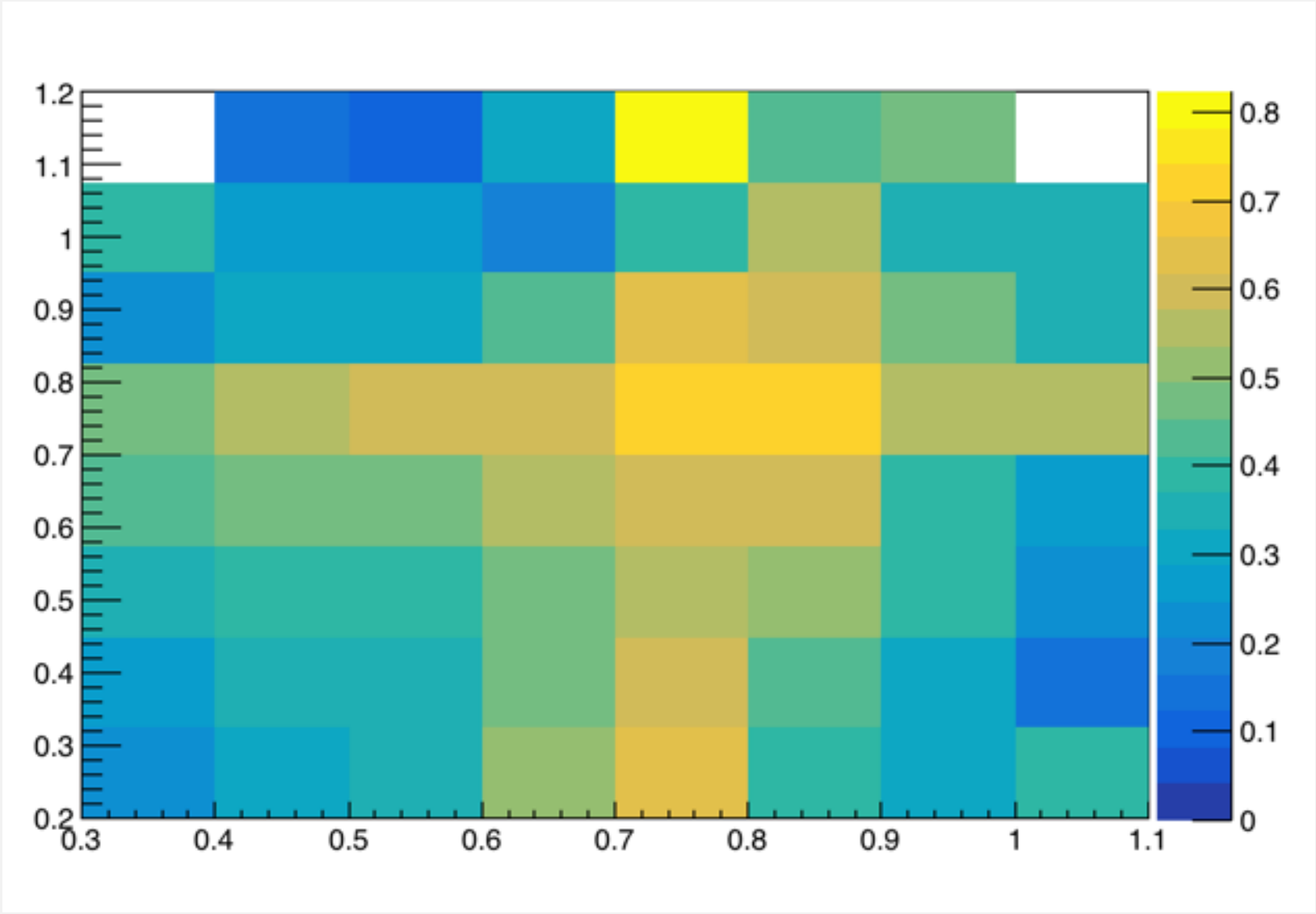
SUME OF THE SIGNAL WITH THE BACKGROUND

$$sume = signal + background$$

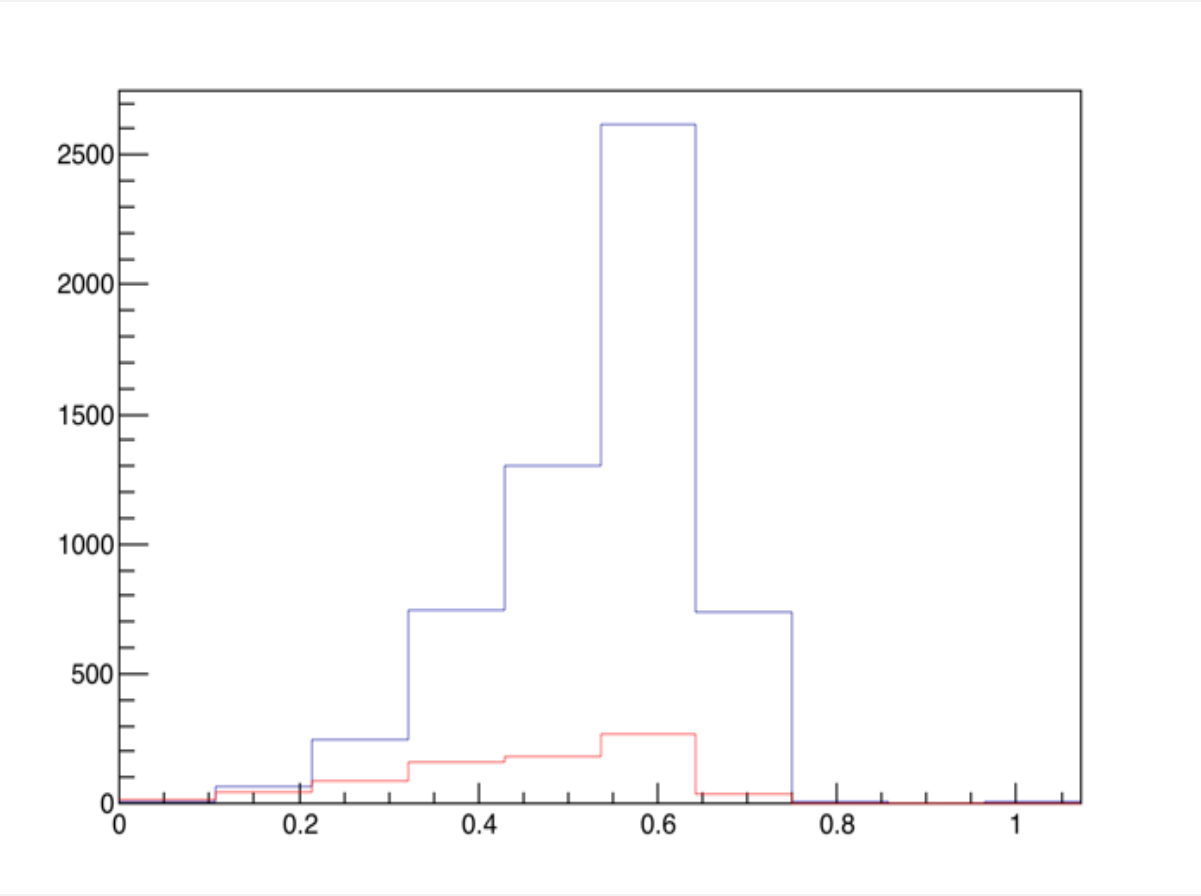


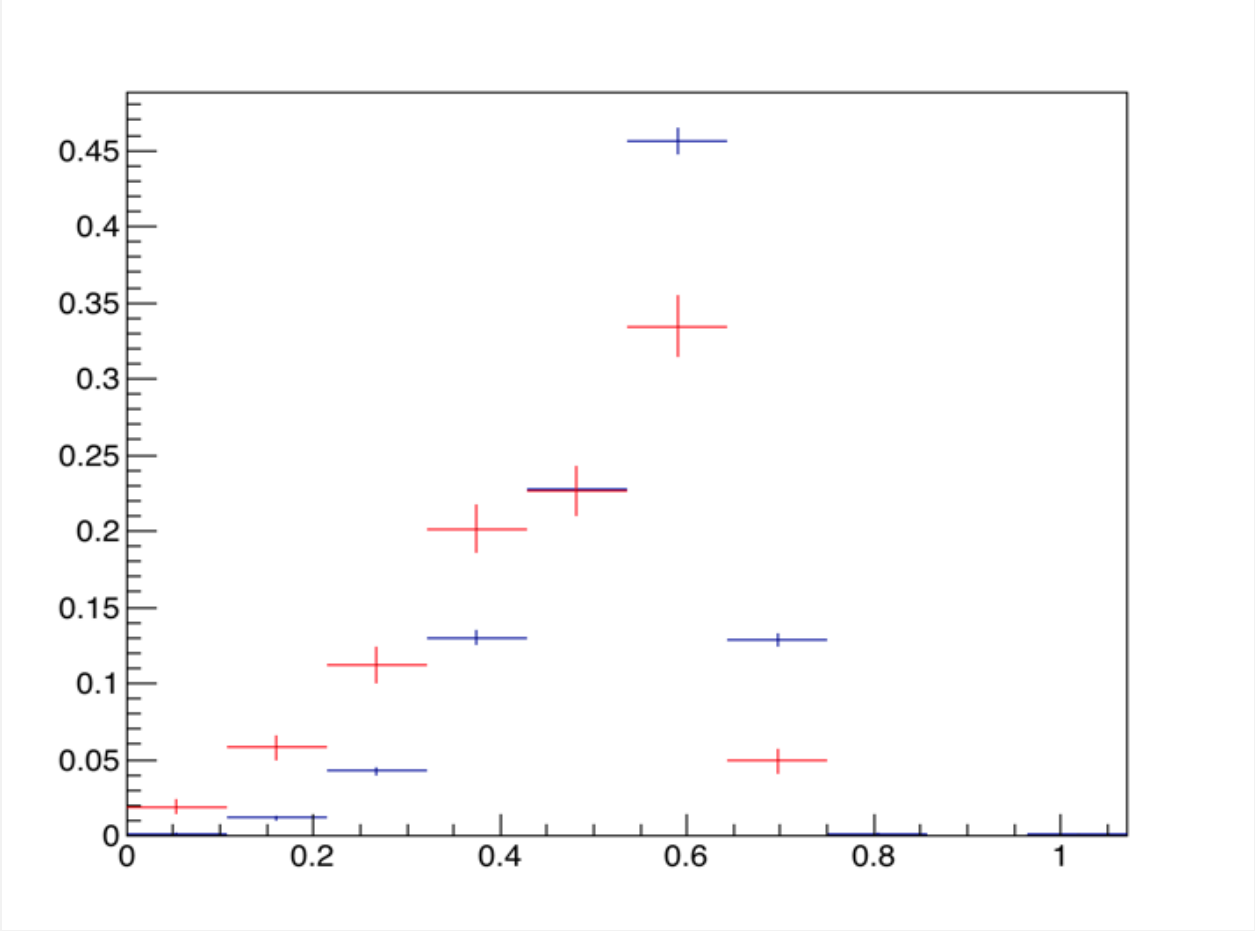
RATIO PARAMETER

$$ratio = \frac{signal}{signal + background}$$



RATIO DISTRIBUTIONS FOR SIGNAL AND BACKGROUND





CONCLUSION

- Two possible parameters to improve the purity of our taus

RATIO
SIGNAL VS BACKGROUND