

Professores: Dilson de Jesus Damião, Eliza Melo da Costa e Mauricio Thiel

Name: Bruno Kron Guandalini e Pedro Oliveira

EXERCICIO 1

Utilizando as amostras do seu grupo, façam um código que:

- plote as distribuições de p_T , η e ϕ dos objetos de estado final (léptons e jatos)
- calcule a massa invariante dos dois léptons com maior p_T e plote-a
$$M^2 = 2p_{T1}p_{T2} (\cosh(\eta_1 - \eta_2) - \cos(\phi_1 - \phi_2))$$
- salve as figuras no formato png
- adicione, tanto o código quanto os plots, no github 18

RESPOSTA:

```
1 #include <TTree.h>
2 #include <TTreeReader.h>
3 #include <TTreeReaderArray.h>
4 #include <TCanvas.h>
5 #include <TH1F.h>
6 #include <TMath.h>
7 #include <iostream>
8 #include <vector>
9 #include <filesystem>
10 #include <algorithm>
11 #include <string>
12
13 double calcular_massa_invariante(const std::vector<float>& pt, const std::vector<
    float>& eta, const std::vector<float>& phi) {
14     if (pt.size() >= 2) {
15         return sqrt(2 * pt[0] * pt[1] * (TMath::CosH(eta[0] - eta[1]) - TMath::Cos(
            phi[0] - phi[1])));
16     }
17     return -1.0;
18 }
19
20 void Relatividade() {
21     std::string diretorio = "/opendata/eos/opendata/cms/Run2016G/DoubleEG/NANOA0D/
        UL2016_MiniA0Dv2_NanoA0Dv9-v1/250000";
22
23     std::vector<double> e_massas_invariantes;
24
25     TH1F* hElectronPt = new TH1F("hElectronPt", "Electron p_{T} Distribution", 50, 0,
        200);
26     TH1F* hMuonPt = new TH1F("hMuonPt", "Muon p_{T} Distribution", 50, 0, 200);
27     TH1F* hTauPt = new TH1F("hTauPt", "Tau p_{T} Distribution", 50, 0, 200);
28     TH1F* hJetPt = new TH1F("hJetPt", "Jet p_{T} Distribution", 50, 0, 200);
29 }
```

```

30  TH1F* hElectronEta = new TH1F("hElectronEta", "Electron #eta Distribution", 50,
    -5, 5);
31  TH1F* hMuonEta = new TH1F("hMuonEta", "Muon #eta Distribution", 50, -5, 5);
32  TH1F* hTauEta = new TH1F("hTauEta", "Tau #eta Distribution", 50, -5, 5);
33  TH1F* hJetEta = new TH1F("hJetEta", "Jet #eta Distribution", 50, -5, 5);
34
35  TH1F* hElectronPhi = new TH1F("hElectronPhi", "Electron #phi Distribution", 50,
    -3.14, 3.14);
36  TH1F* hMuonPhi = new TH1F("hMuonPhi", "Muon #phi Distribution", 50, -3.14, 3.14);
37  TH1F* hTauPhi = new TH1F("hTauPhi", "Tau #phi Distribution", 50, -3.14, 3.14);
38  TH1F* hJetPhi = new TH1F("hJetPhi", "Jet #phi Distribution", 50, -3.14, 3.14);
39
40  for (const auto& entry : std::filesystem::directory_iterator(diretorio)) {
41      std::string file_path = entry.path();
42      TFile file(file_path.c_str(), "READ");
43      if (!file.IsOpen()) continue;
44
45      TTreeReader reader("Events", &file);
46      TTreeReaderArray<float> Electron_pt(reader, "Electron_pt");
47      TTreeReaderArray<float> Electron_eta(reader, "Electron_eta");
48      TTreeReaderArray<float> Electron_phi(reader, "Electron_phi");
49      TTreeReaderArray<float> Muon_pt(reader, "Muon_pt");
50      TTreeReaderArray<float> Muon_eta(reader, "Muon_eta");
51      TTreeReaderArray<float> Muon_phi(reader, "Muon_phi");
52      TTreeReaderArray<float> Jet_pt(reader, "Jet_pt");
53      TTreeReaderArray<float> Jet_eta(reader, "Jet_eta");
54      TTreeReaderArray<float> Jet_phi(reader, "Jet_phi");
55      TTreeReaderArray<float> Tau_pt(reader, "Tau_pt");
56      TTreeReaderArray<float> Tau_eta(reader, "Tau_eta");
57      TTreeReaderArray<float> Tau_phi(reader, "Tau_phi");
58
59      while (reader.Next()) {
60          for (size_t i = 0; i < Electron_pt.GetSize(); ++i) {
61              hElectronPt->Fill(Electron_pt[i]);
62              hElectronEta->Fill(Electron_eta[i]);
63              hElectronPhi->Fill(Electron_phi[i]);
64          }
65          for (size_t i = 0; i < Muon_pt.GetSize(); ++i) {
66              hMuonPt->Fill(Muon_pt[i]);
67              hMuonEta->Fill(Muon_eta[i]);
68              hMuonPhi->Fill(Muon_phi[i]);
69          }
70          for (size_t i = 0; i < Jet_pt.GetSize(); ++i) {
71              hJetPt->Fill(Jet_pt[i]);
72              hJetEta->Fill(Jet_eta[i]);
73              hJetPhi->Fill(Jet_phi[i]);
74          }
75          for (size_t i = 0; i < Tau_pt.GetSize(); ++i) {
76              hTauPt->Fill(Tau_pt[i]);
77              hTauEta->Fill(Tau_eta[i]);
78              hTauPhi->Fill(Tau_phi[i]);
79          }
80
81          std::vector<std::pair<float, int>> leptons;
82          for (size_t i = 0; i < Electron_pt.GetSize(); ++i) {
83              leptons.emplace_back(Electron_pt[i], i);
84          }
85          for (size_t i = 0; i < Muon_pt.GetSize(); ++i) {
86              leptons.emplace_back(Muon_pt[i], i + Electron_pt.GetSize());
87          }
88          for (size_t i = 0; i < Tau_pt.GetSize(); ++i) {
89              leptons.emplace_back(Tau_pt[i], i + Electron_pt.GetSize() + Muon_pt.
                GetSize());

```

```

90     }
91
92     std::sort(leptons.rbegin(), leptons.rend());
93
94     if (leptons.size() >= 2) {
95         int idx1 = leptons[0].second;
96         int idx2 = leptons[1].second;
97
98         float pt1, eta1, phi1, pt2, eta2, phi2;
99
100        if (idx1 < Electron_pt.GetSize()) {
101            pt1 = Electron_pt[idx1];
102            eta1 = Electron_eta[idx1];
103            phi1 = Electron_phi[idx1];
104        } else if (idx1 < Electron_pt.GetSize() + Muon_pt.GetSize()) {
105            pt1 = Muon_pt[idx1 - Electron_pt.GetSize()];
106            eta1 = Muon_eta[idx1 - Electron_pt.GetSize()];
107            phi1 = Muon_phi[idx1 - Electron_pt.GetSize()];
108        } else {
109            pt1 = Tau_pt[idx1 - Electron_pt.GetSize() - Muon_pt.GetSize()];
110            eta1 = Tau_eta[idx1 - Electron_pt.GetSize() - Muon_pt.GetSize()];
111            phi1 = Tau_phi[idx1 - Electron_pt.GetSize() - Muon_pt.GetSize()];
112        }
113
114        if (idx2 < Electron_pt.GetSize()) {
115            pt2 = Electron_pt[idx2];
116            eta2 = Electron_eta[idx2];
117            phi2 = Electron_phi[idx2];
118        } else if (idx2 < Electron_pt.GetSize() + Muon_pt.GetSize()) {
119            pt2 = Muon_pt[idx2 - Electron_pt.GetSize()];
120            eta2 = Muon_eta[idx2 - Electron_pt.GetSize()];
121            phi2 = Muon_phi[idx2 - Electron_pt.GetSize()];
122        } else {
123            pt2 = Tau_pt[idx2 - Electron_pt.GetSize() - Muon_pt.GetSize()];
124            eta2 = Tau_eta[idx2 - Electron_pt.GetSize() - Muon_pt.GetSize()];
125            phi2 = Tau_phi[idx2 - Electron_pt.GetSize() - Muon_pt.GetSize()];
126        }
127
128        std::vector<float> pt_values = {pt1, pt2};
129        std::vector<float> eta_values = {eta1, eta2};
130        std::vector<float> phi_values = {phi1, phi2};
131        double massa_invariante = calcular_massa_invariante(pt_values,
132            eta_values, phi_values);
133
134        if (massa_invariante >= 0) {
135            e_massas_invariantes.push_back(massa_invariante);
136        }
137    }
138 }
139
140
141 TCanvas* canvas;
142
143 canvas = new TCanvas("canvasElectronPt", "Electron p_{T} Distribution", 800, 600)
144 ;
145 hElectronPt->SetLineColor(kBlue);
146 hElectronPt->Draw();
147 hElectronPt->GetXaxis()->SetTitle("p_{T} (GeV/c)");
148 hElectronPt->GetYaxis()->SetTitle("Events");
149 canvas->SaveAs("electron_pt_distribution.png");
150 delete canvas;

```

```

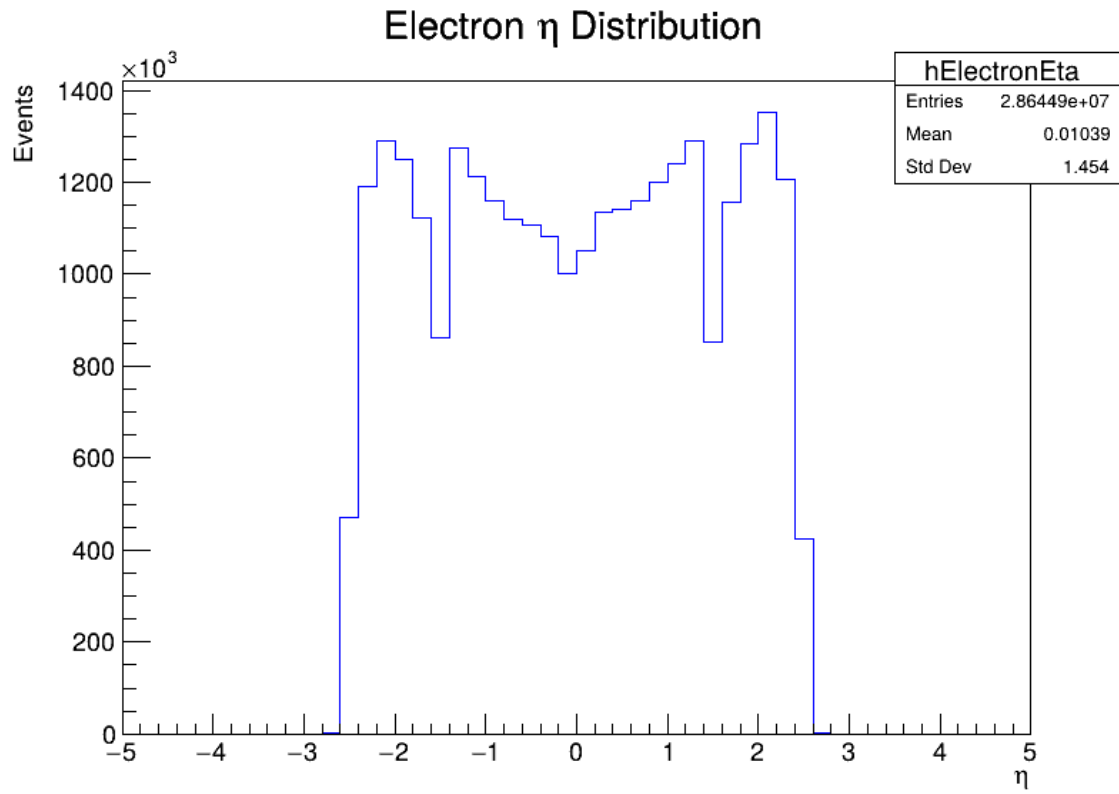
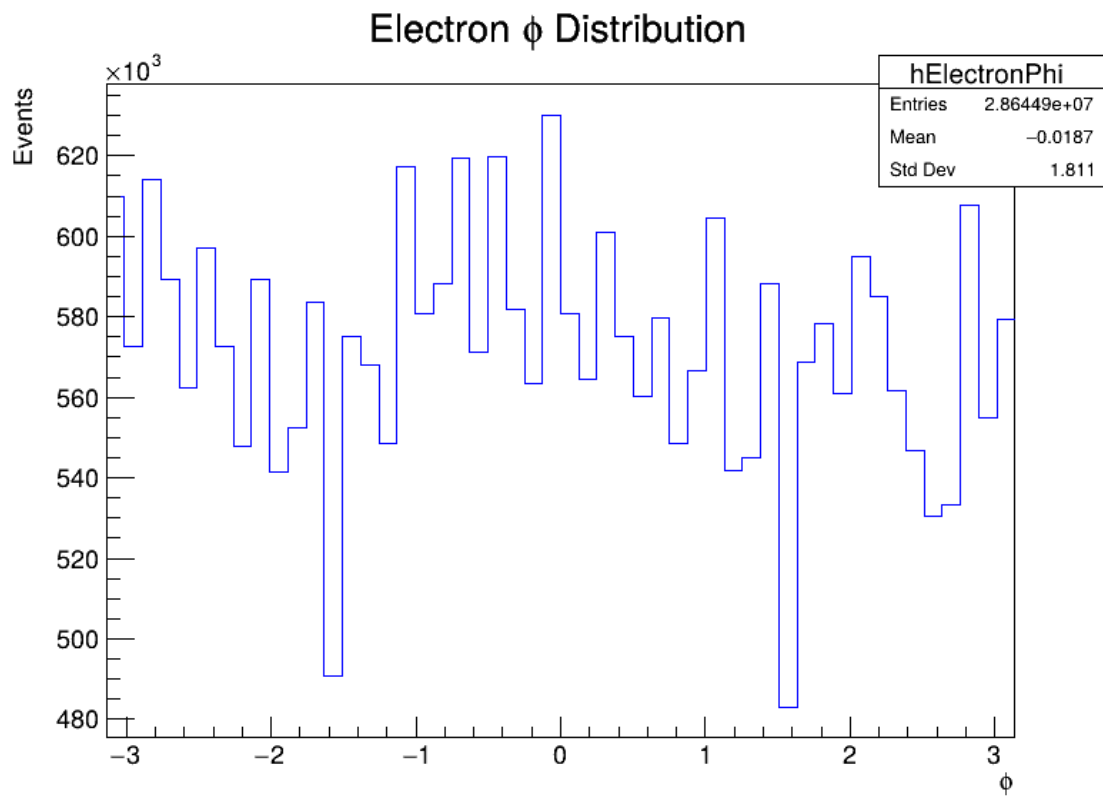
151 canvas = new TCanvas("canvasMuonPt", "Muon p_{T} Distribution", 800, 600);
152 hMuonPt->SetLineColor(kRed);
153 hMuonPt->Draw();
154 hMuonPt->GetXaxis()->SetTitle("p_{T} (GeV/c)");
155 hMuonPt->GetYaxis()->SetTitle("Events");
156 canvas->SaveAs("muon_pt_distribution.png");
157 delete canvas;
158
159 canvas = new TCanvas("canvasTauPt", "Tau p_{T} Distribution", 800, 600);
160 hTauPt->SetLineColor(kMagenta);
161 hTauPt->Draw();
162 hTauPt->GetXaxis()->SetTitle("p_{T} (GeV/c)");
163 hTauPt->GetYaxis()->SetTitle("Events");
164 canvas->SaveAs("tau_pt_distribution.png");
165 delete canvas;
166
167 canvas = new TCanvas("canvasJetPt", "Jet p_{T} Distribution", 800, 600);
168 hJetPt->SetLineColor(kGreen);
169 hJetPt->Draw();
170 hJetPt->GetXaxis()->SetTitle("p_{T} (GeV/c)");
171 hJetPt->GetYaxis()->SetTitle("Events");
172 canvas->SaveAs("jet_pt_distribution.png");
173 delete canvas;
174
175 canvas = new TCanvas("canvasElectronEta", "Electron #eta Distribution", 800, 600)
176 ;
177 hElectronEta->SetLineColor(kBlue);
178 hElectronEta->Draw();
179 hElectronEta->GetXaxis()->SetTitle("#eta");
180 hElectronEta->GetYaxis()->SetTitle("Events");
181 canvas->SaveAs("electron_eta_distribution.png");
182 delete canvas;
183
184 canvas = new TCanvas("canvasMuonEta", "Muon #eta Distribution", 800, 600);
185 hMuonEta->SetLineColor(kRed);
186 hMuonEta->Draw();
187 hMuonEta->GetXaxis()->SetTitle("#eta");
188 hMuonEta->GetYaxis()->SetTitle("Events");
189 canvas->SaveAs("muon_eta_distribution.png");
190 delete canvas;
191
192 canvas = new TCanvas("canvasTauEta", "Tau #eta Distribution", 800, 600);
193 hTauEta->SetLineColor(kMagenta);
194 hTauEta->Draw();
195 hTauEta->GetXaxis()->SetTitle("#eta");
196 hTauEta->GetYaxis()->SetTitle("Events");
197 canvas->SaveAs("tau_eta_distribution.png");
198 delete canvas;
199
200 canvas = new TCanvas("canvasJetEta", "Jet #eta Distribution", 800, 600);
201 hJetEta->SetLineColor(kGreen);
202 hJetEta->Draw();
203 hJetEta->GetXaxis()->SetTitle("#eta");
204 hJetEta->GetYaxis()->SetTitle("Events");
205 canvas->SaveAs("jet_eta_distribution.png");
206 delete canvas;
207
208 canvas = new TCanvas("canvasElectronPhi", "Electron #phi Distribution", 800, 600)
209 ;
210 hElectronPhi->SetLineColor(kBlue);
211 hElectronPhi->Draw();
212 hElectronPhi->GetXaxis()->SetTitle("#phi");
213 hElectronPhi->GetYaxis()->SetTitle("Events");

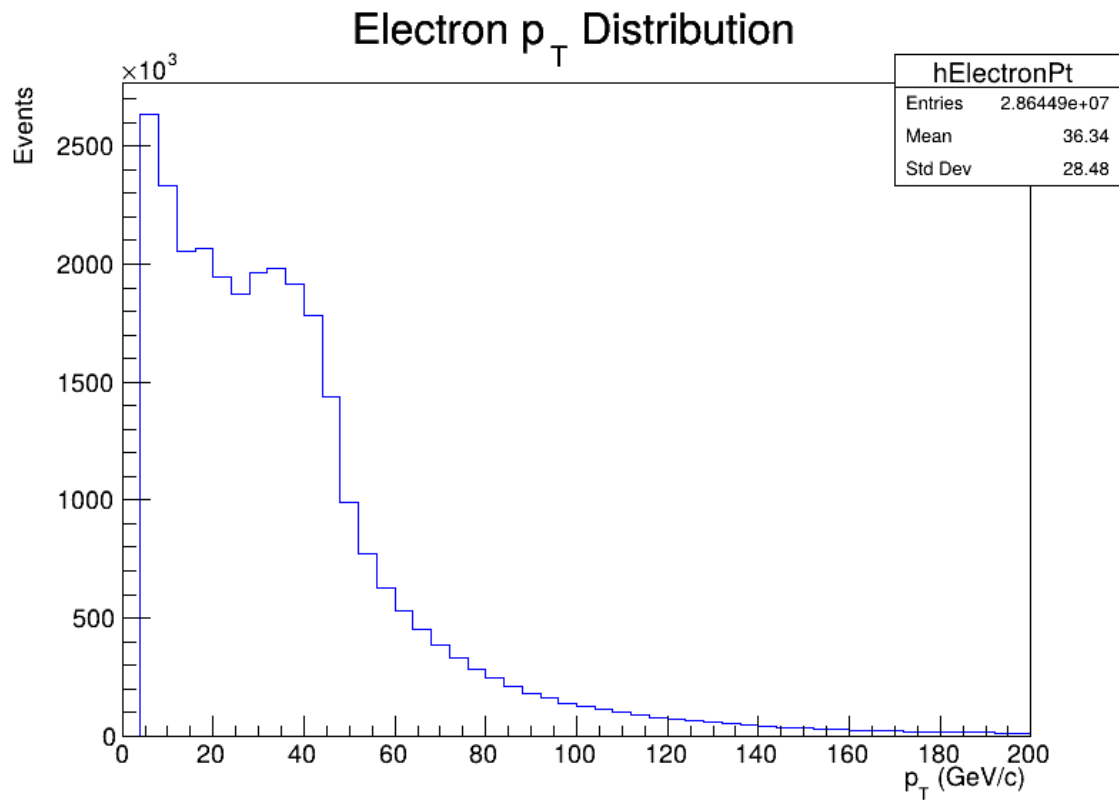
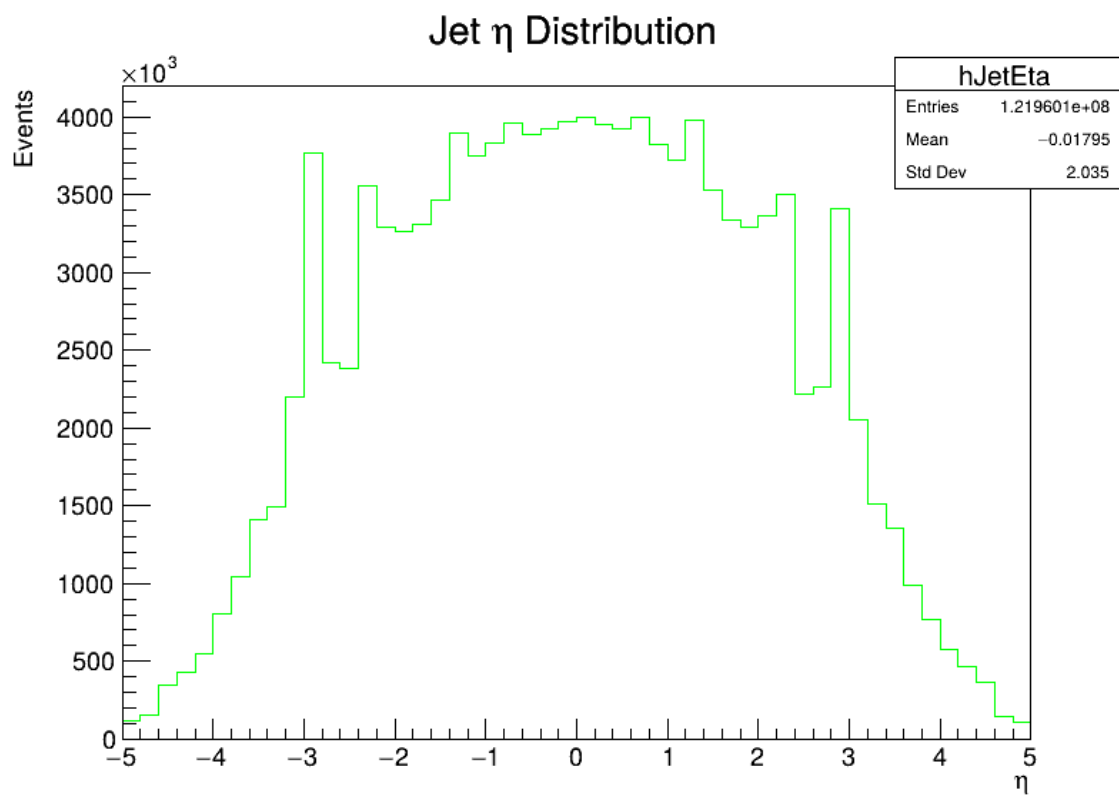
```

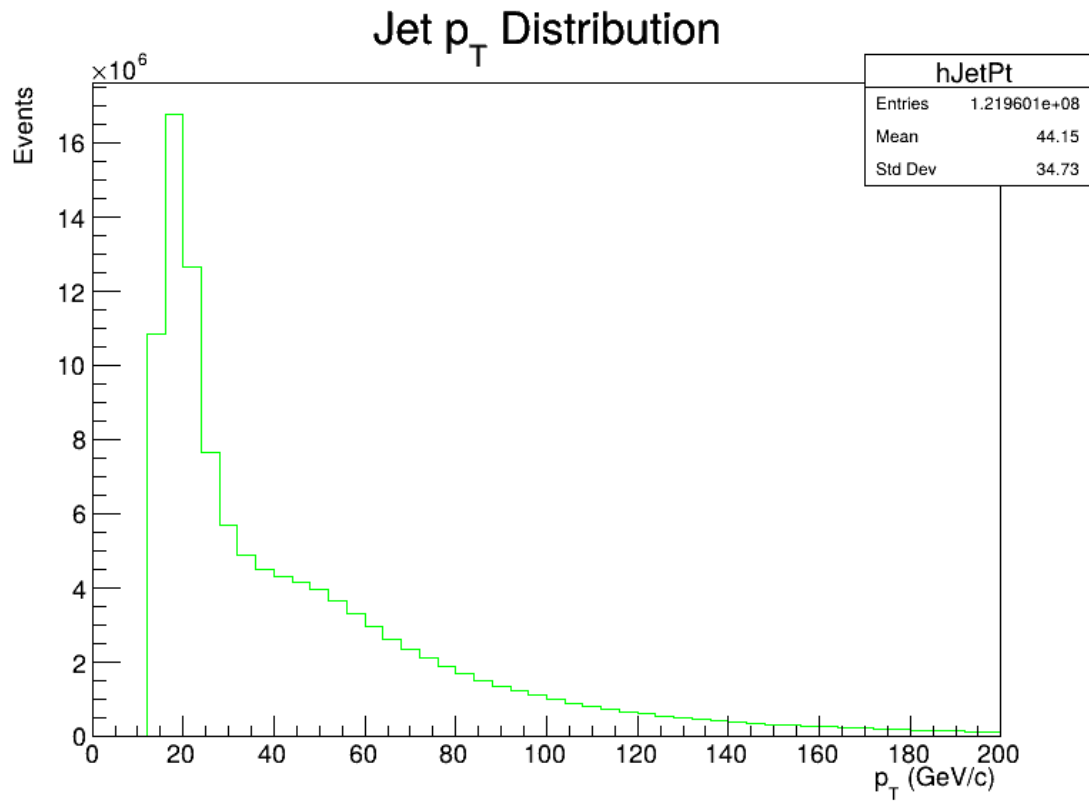
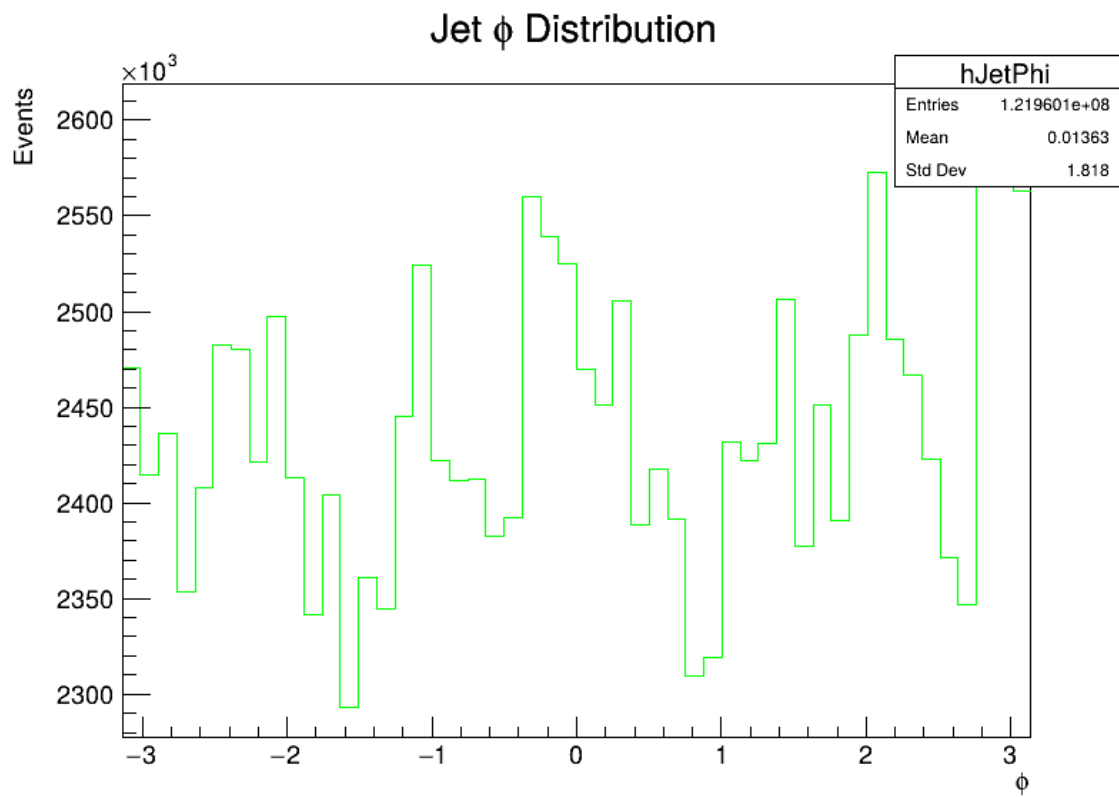
```

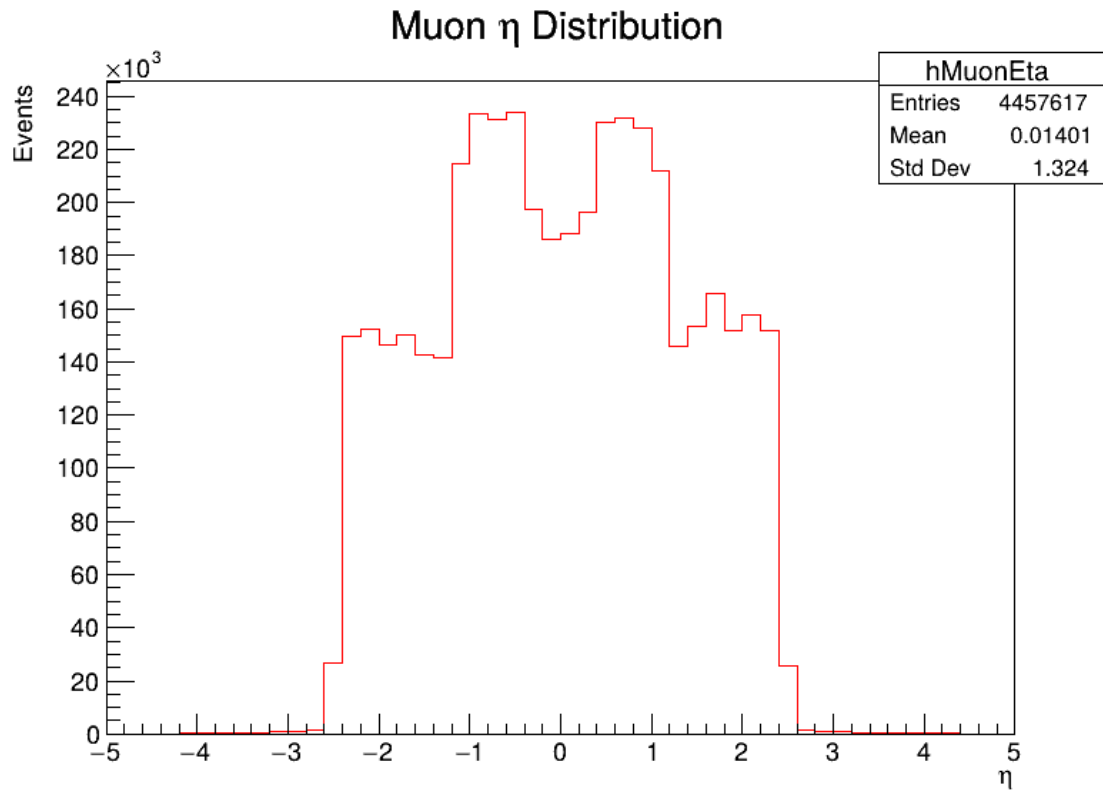
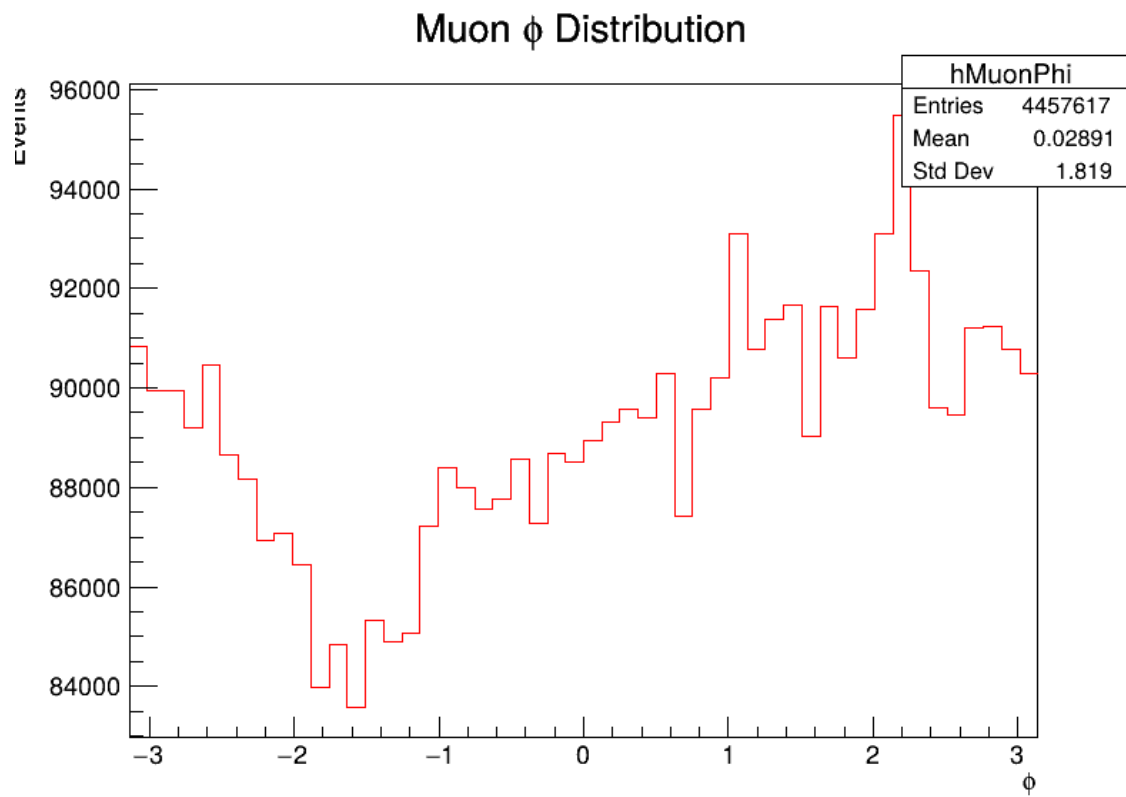
212 canvas->SaveAs("electron_phi_distribution.png");
213 delete canvas;
214
215 canvas = new TCanvas("canvasMuonPhi", "Muon #phi Distribution", 800, 600);
216 hMuonPhi->SetLineColor(kRed);
217 hMuonPhi->Draw();
218 hMuonPhi->GetXaxis()->SetTitle("#phi");
219 hMuonPhi->GetYaxis()->SetTitle("Events");
220 canvas->SaveAs("muon_phi_distribution.png");
221 delete canvas;
222
223 canvas = new TCanvas("canvasTauPhi", "Tau #phi Distribution", 800, 600);
224 hTauPhi->SetLineColor(kMagenta);
225 hTauPhi->Draw();
226 hTauPhi->GetXaxis()->SetTitle("#phi");
227 hTauPhi->GetYaxis()->SetTitle("Events");
228 canvas->SaveAs("tau_phi_distribution.png");
229 delete canvas;
230
231 canvas = new TCanvas("canvasJetPhi", "Jet #phi Distribution", 800, 600);
232 hJetPhi->SetLineColor(kGreen);
233 hJetPhi->Draw();
234 hJetPhi->GetXaxis()->SetTitle("#phi");
235 hJetPhi->GetYaxis()->SetTitle("Events");
236 canvas->SaveAs("jet_phi_distribution.png");
237 delete canvas;
238
239 TH1F* hMassaInvariante = new TH1F("hMassaInvariante", "Invariant Mass
Distribution", 50, 0, 200);
240 for (const auto& massa : e_massas_invariantes) {
241     if (massa >= 0) hMassaInvariante->Fill(massa);
242 }
243
244 canvas = new TCanvas("canvasInvariantMass", "Invariant Mass Distribution", 800,
600);
245 hMassaInvariante->SetLineColor(kBlack);
246 canvas->SetLogy();
247 hMassaInvariante->Draw();
248 hMassaInvariante->GetXaxis()->SetTitle("Invariant Mass (GeV/c^{2})");
249 hMassaInvariante->GetYaxis()->SetTitle("Events");
250 canvas->SaveAs("invariant_mass_distribution.png");
251 delete canvas;
252
253
254 delete hElectronPt;
255 delete hMuonPt;
256 delete hTauPt;
257 delete hJetPt;
258 delete hElectronEta;
259 delete hMuonEta;
260 delete hTauEta;
261 delete hJetEta;
262 delete hElectronPhi;
263 delete hMuonPhi;
264 delete hTauPhi;
265 delete hJetPhi;
266 delete hMassaInvariante;
267 }

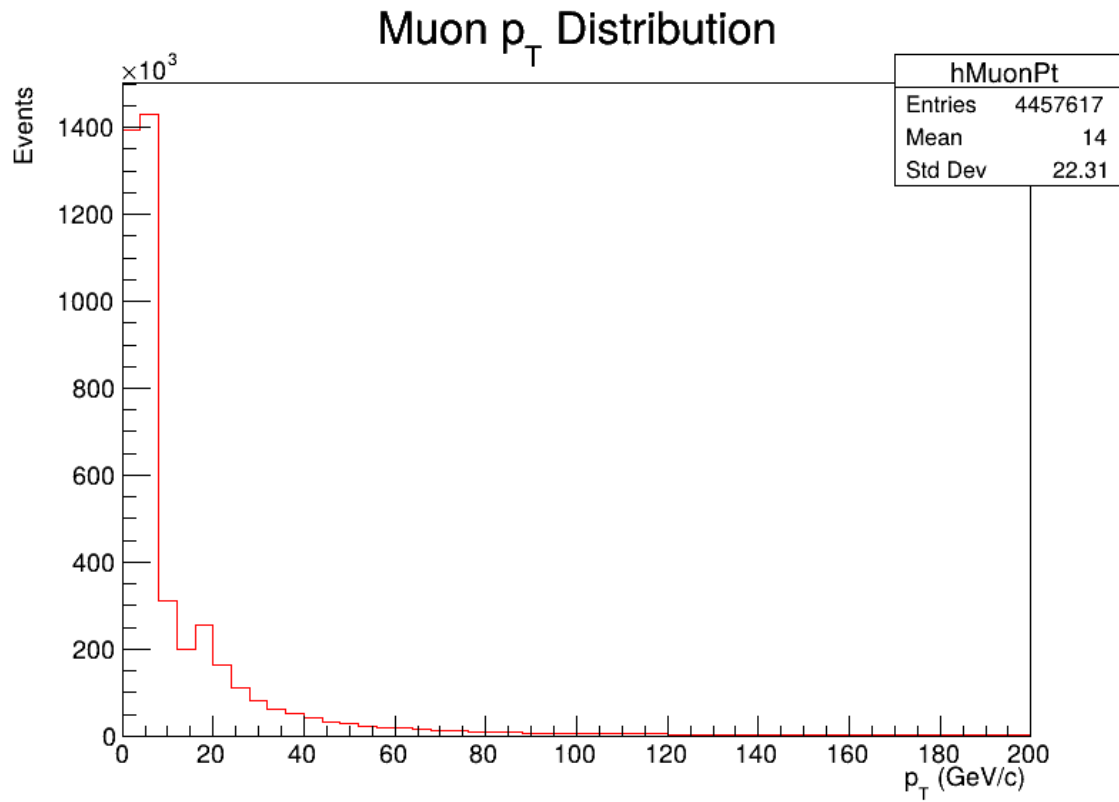
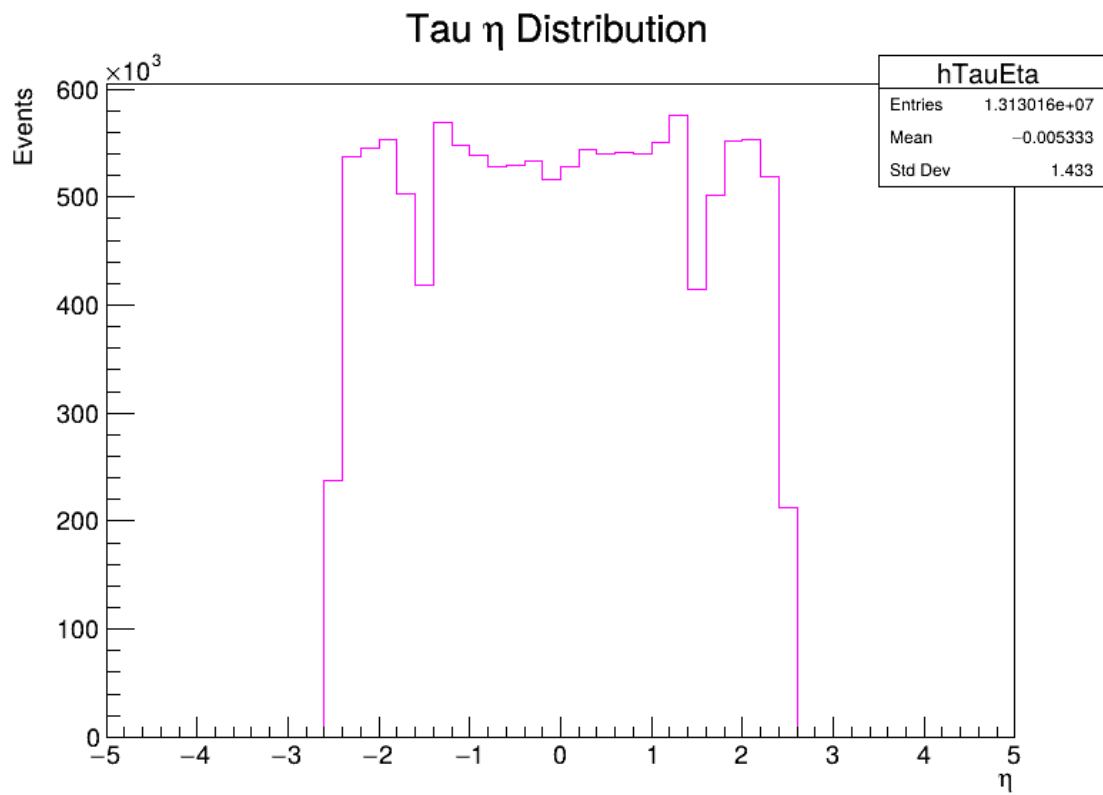
```

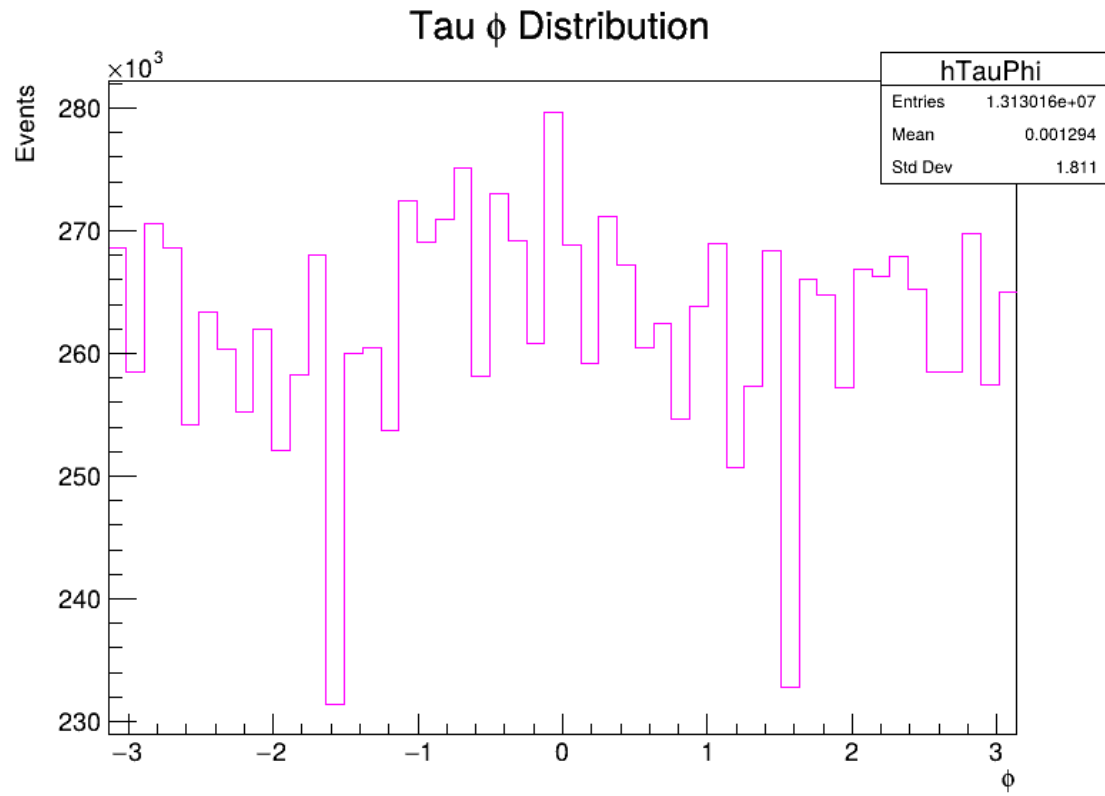
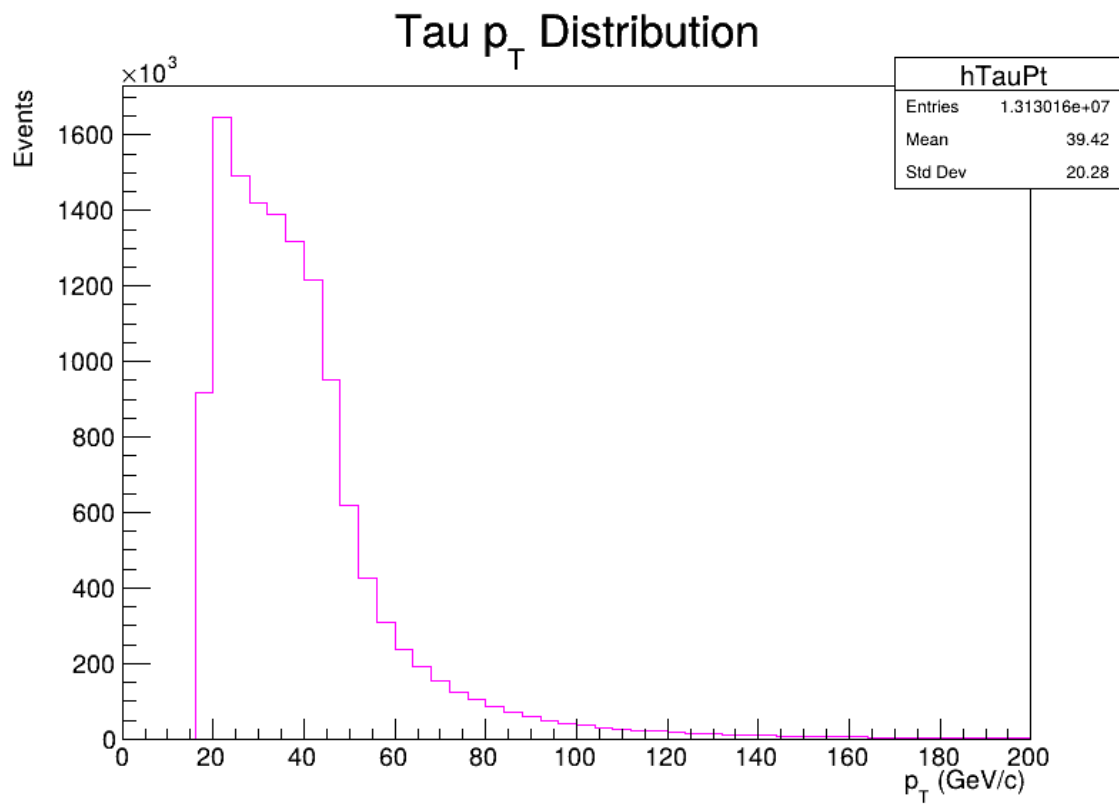
Figura 1: η do ElétronFigura 2: ϕ do Elétron

Figura 3: p_T do ElétronFigura 4: η do Jato

Figura 5: p_T do JatoFigura 6: ϕ do Jato

Figura 7: η do MúonFigura 8: ϕ do Múon

Figura 9: p_T do MúonFigura 10: η do Tau

Figura 11: ϕ do TauFigura 12: p_T do Tau

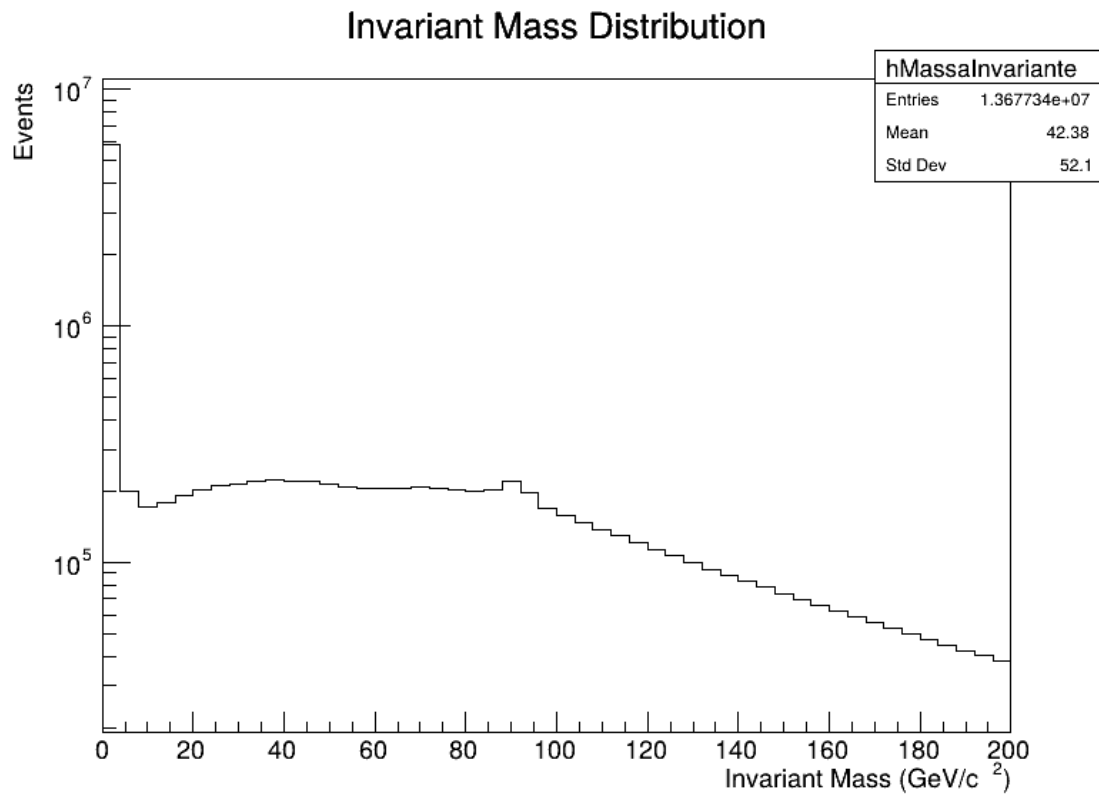


Figura 13: Massa Invariante