ÖAW AUSTRIAN ACADEMY OF SCIENCES

SMI – STEFAN MEYER INSTITUTE FOR SUBATOMIC PHYSICS

Tau 2023 data analysis

internal

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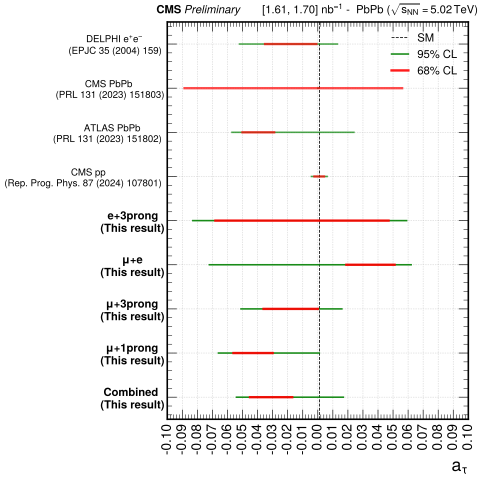
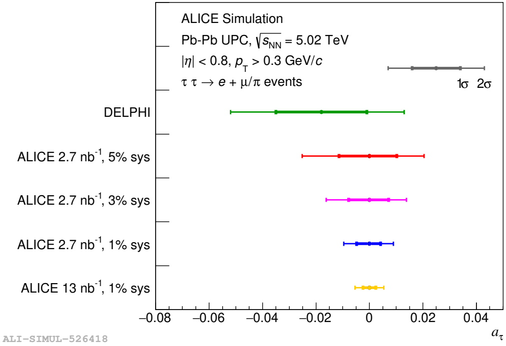
Dec 12, 2024, Prague

ALICE

CERN

Current state-of-the-art





Data set

Monte Carlo

- Unofficial simulation, 1.5M generated events.
  - Official underway.
- $\gamma\gamma \rightarrow \tau\tau$ generated with Upcgen.
- τs decayed with external Pythia.
- ALICE detector response simulated via o2sim framework
  - Anchored to PbPb2023 pass4.
- Filtered with DGCandProducer locally.
- Analyze with this task.

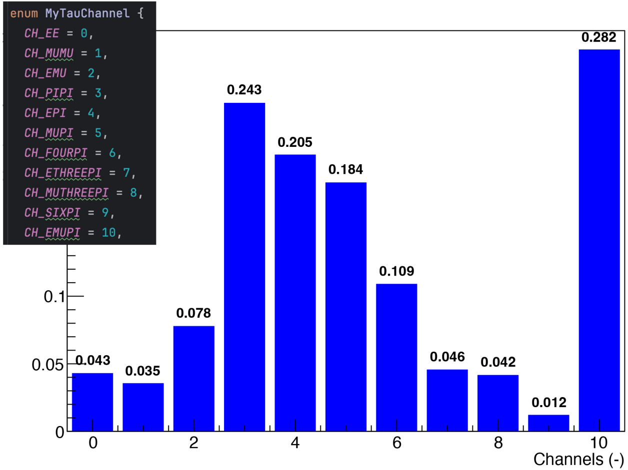
Measured Data

- LHC23PbPb pass4, analysed luminosity of 1.217 nb^{-1}
- Filtered with SGCandProducer (same settings as for MC filter).
- Analyze with the same task.

Monte Carlo

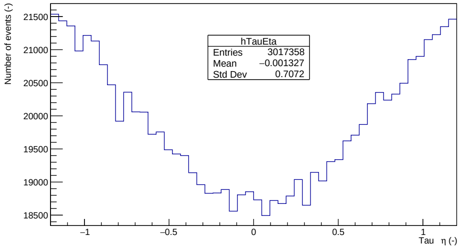
Truth level

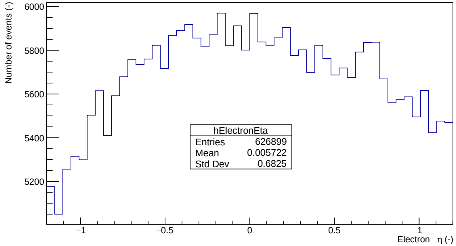
- $\tau \to e^+e^-$: 3.175%
- $\tau \to \mu^+\mu^-$: 3.02%
- $\tau \to \pi^+\pi^-$: 21.8%
- $\tau \to e^\pm\mu^\pm$: 6.198%
- $\tau \to e^\pm\pi^\pm$: 16.66%
- $\tau \to \mu^\pm\pi^\pm$: 16.26%
- $\tau \to \pi^+\pi^-\pi^+\pi^-$: 13.6%
- $\tau \to e^\pm\pi^\pm\pi^\mp\pi^\pm$: 5.185%
- $\tau \to \mu^\pm\pi^\pm\pi^\mp\pi^\pm$: 5.06%
- $\tau \to \pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$: 2.117%
- $\tau \to e^\pm\mu^\mp(\pi^\mp)$: 22.86%

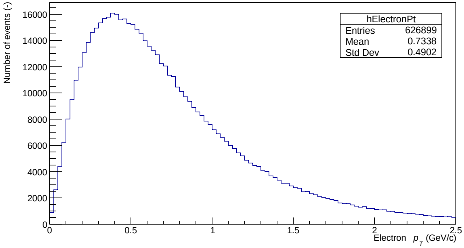


- In total 427780 $e^\pm\mu^\mp(\pi^\mp)$ events.

- No initial eta cut → huge loss on acceptance/efficiency/whatever-people-call-it







Monte Carlo
Reconstruction level

Track selection

- isPVcontributor $=$ track has assigned primary vertex.
- $p_{\mathrm{T}} \in (0.1, \infty)$ GeV/c && $\eta < |0.8|$ && $\mathrm{DCA}_{xy}^{p_{\mathrm{T}}-\mathrm{dep}}$=0.045 && $\mathrm{DCA}_z = 2$ cm
- ITS:
  - HasITS && Hit in any innermost layer.
  - $\mathrm{nClusters}_{\mathrm{ITS}} > 1$, $\chi^2_{\mathrm{ITS}} > 36$.
- TPC:
  - HasTPC && Hit in any innermost layer.
  - $\mathrm{nClusters}_{\mathrm{TPC}} > 70$, $\chi^2_{\mathrm{TPC}} > 4$.
  - nCrossedRowsOverFindableClusters$>$ 0.8.

PID algorithm

- Based on nSigma hypothesis for each particle in TPC and TOF:
- use TPC smallest nSigma hypothesis to assign particle.
- Details on GitHub in testPIDhypothesis function.

Electron+Muon/Pion event selection

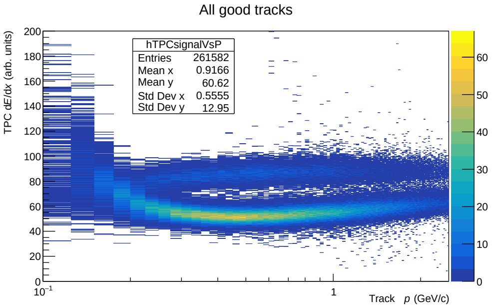
- Tracks have opposite charge.
- Acoplanarity $< 4/5\pi$ rad.
- Identified electron.
    - hits TOF.
    - TPC nSigma electron hypothesis $\in (-1, 2)$

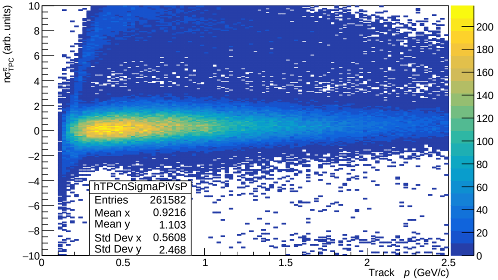
Particle IDentification

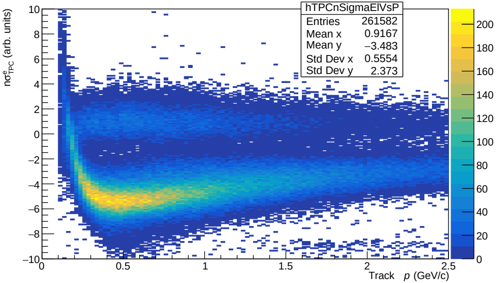
Monte Carlo

Track selection: All good tracks, PID selection: non applied.

- Electrons/muons/pions simulated.
- Electron/Pion/Muon ambiguity at low p.

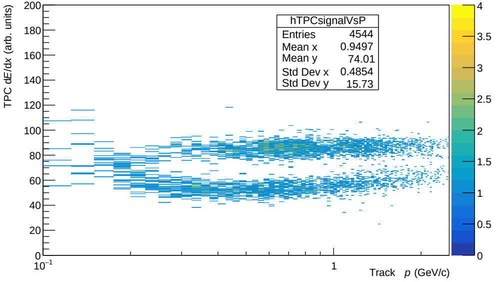


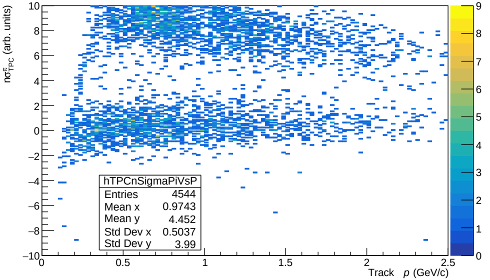


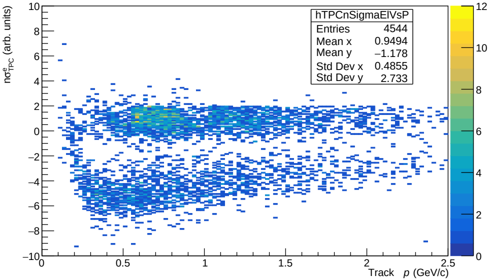


Track selection: Two-tracks events, PID selection: non applied.

- Large decrease, mainly acoplanarity cut?
- Electron/Pion/Muon ambiguity at low p.

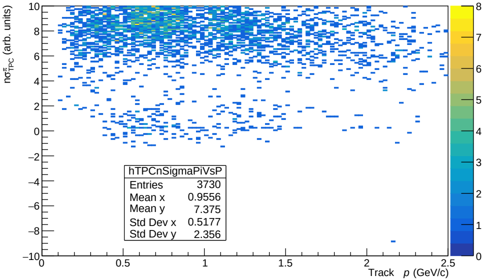


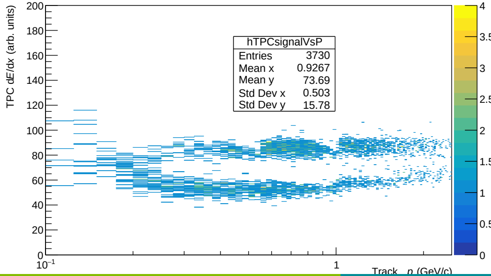


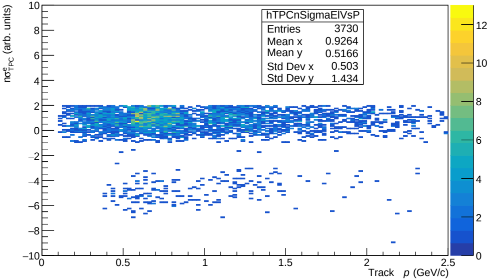


Track selection: Two-tracks events, PID selection: Most probable el/μ/π based on nσ^{TPC}

- Purity-based decision: Some el/μ/π lost at intersections with K/p.
  - Feature of TPC n σ parameterization.
- This accounts for 18% of events.
- Find more in this study.

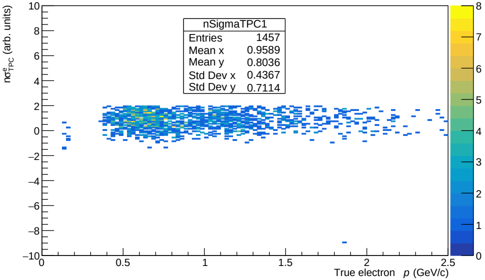


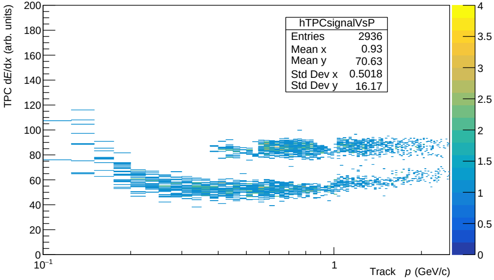


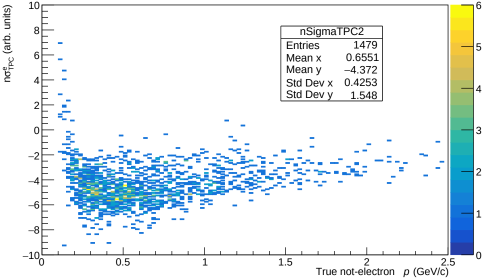


Track selection: Two-tracks events
PID selection: One trk el, the other μ/π

- Electron: TOF hit, $n\sigma^{\mathrm{el}} \in (-1, 2)$.
- Right: Checking truth info:
  - (Almost) perfect $n\sigma$ separation of the tracks.





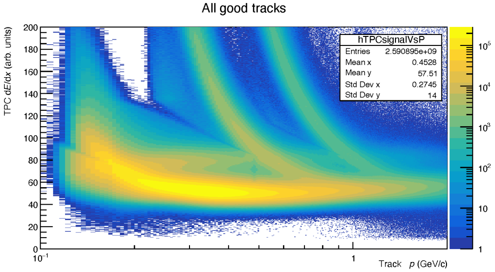


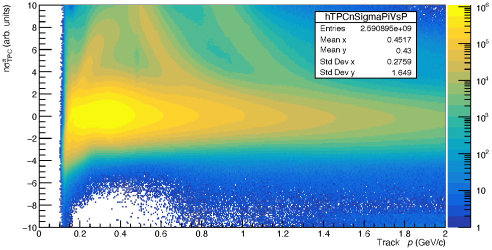
Particle IDentification

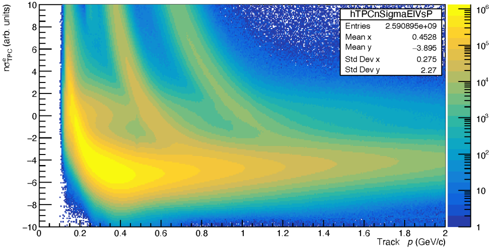
Measured data

Track selection: All good tracks, PID selection: non applied.

- Electrons not supervisible.

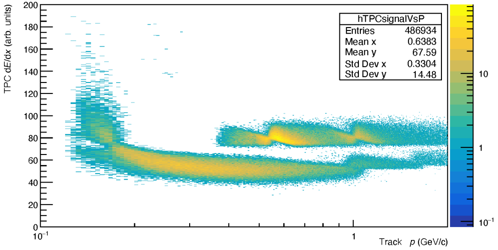


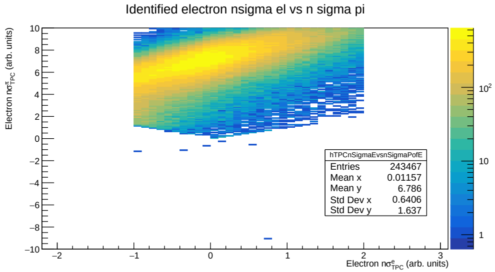




Track selection: Two-tracks events
PID selection: One trk el, the other μ/π

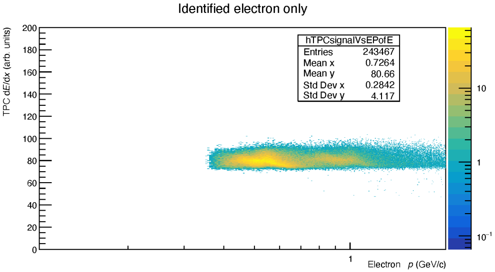
- Electron: TOF hit, $n\sigma^{el} \in (-1, 2)$.
- Right: most electrons too high $\sigma^{ß}$

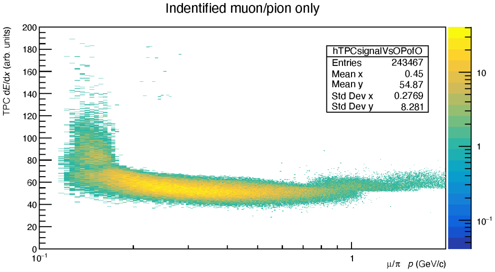


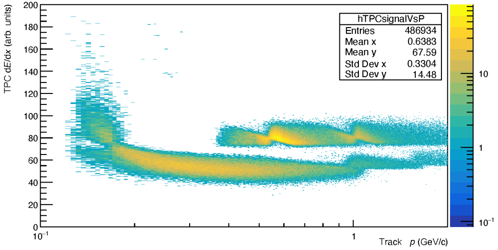


Track selection: Two-tracks events
PID selection: One trk el, the other μ/π

- Electron: TOF hit, $n\sigma^{el} \in (-1, 2)$.
- Bottom: Plot unspecific track.
- Right: Identify electron and μ/π
- Why distributions different?
  - Code snippet in backup.





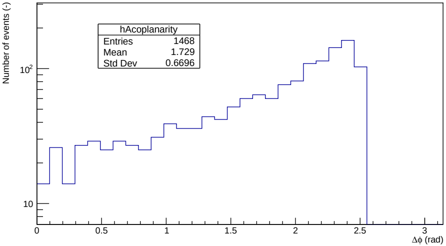


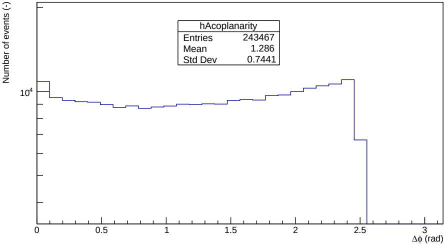
Kinematic plots

Comparison measured data and Monte Carlo

Track selection: Two-tracks events
PID selection: One trk el, the other μ/π

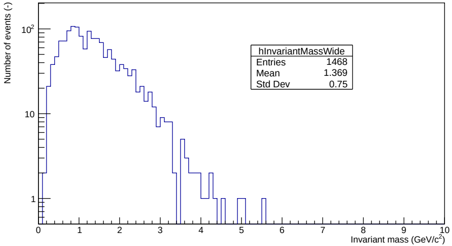
- Top: MC, Bottom: data
- Cutting out back-to-back tracks.
- Flatter in data → strong contamination of other events.
  - How to identify it?



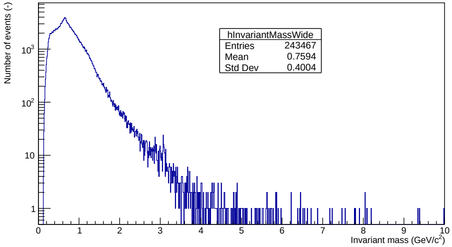


Track selection: Two-tracks events
PID selection: One trk el, the other μ/π

- Top: MC, Bottom: data
- Clear ρ^0 and J/ψ peaks.
- Must be the incoherent events.
- How to cut them out?
- What could be that peak at ≈2.9?

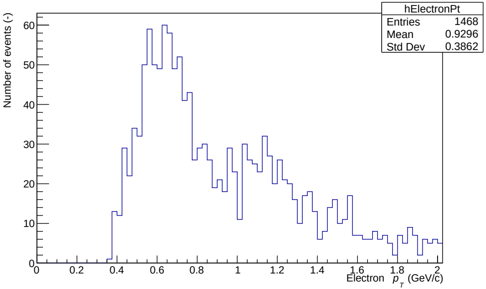


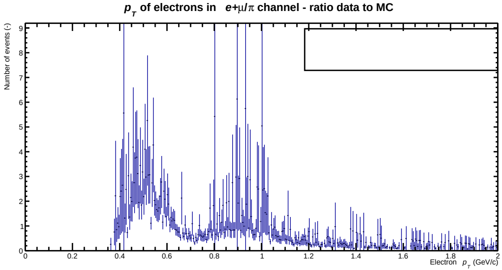
Two-track system

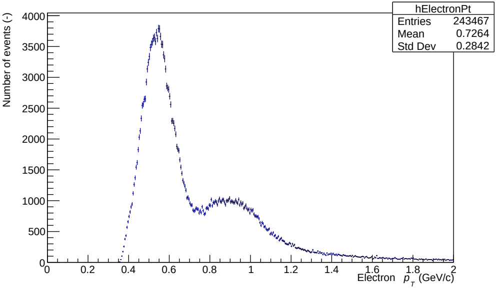


Track selection: Two-tracks events
PID selection: One trk el, the other μ/π

- Top: MC, Bottom: data
- Both shows two-peak structure
  - MC and data slightly shifted
  - What is the second bump?

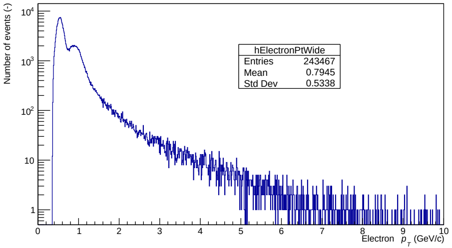


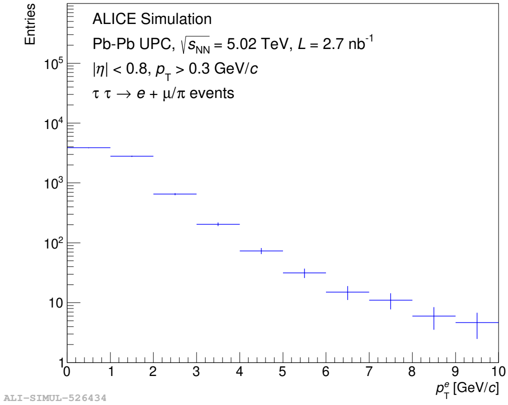




Track selection: Two-tracks events
PID selection: One trk el, the other μ/π

- Comparison to older Run2 anchored simulations at 50kHz.
  - Around 6k reco events $\rightarrow$ 3k expected for Run 2 detector acceptance/efficiency/whatever





Conclusion and plans

Findings:

- ??

Open questions:

- What is the rest contamination?
- What role occupancy effect might play?
- When is the last time you thought about The Roman Empire?

Next step:

- Make official simulation with eta cut on truth level.
- Make embedded simulation.
- Cut the data sample based on electron momentum to avoid junctions with others.
- Get AxE and make cross section.
- Make the money plot.

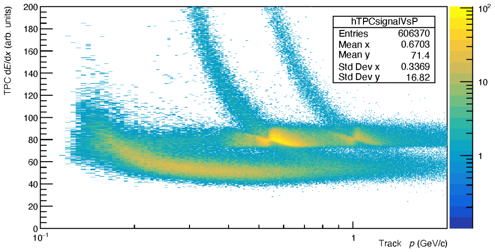
BACK UP

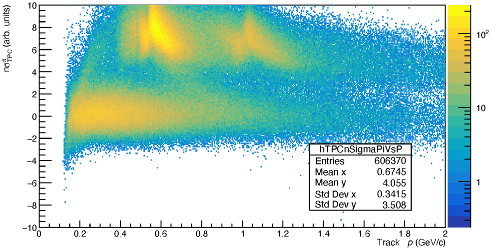
Code snippet for mupi histos filling.

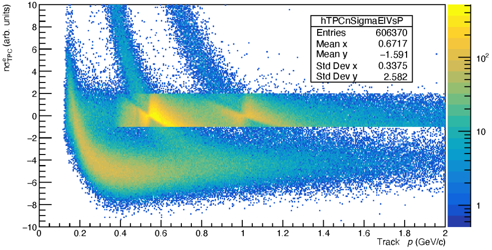
```cpp
struct UpcTauCentralBarrelRL {
  void fillPIDhistograms(C const& /*reconstructedCollision*/, Ts const& reconstructedBarrelTracks)
        if ((countPVGTelectrons == 1 && countPVGTmuons == 1) || (countPVGTelectrons == 1 && countPVGTpions == 1)) {
          histos.get<TH2>(HIST("EventTwoTracks/ElectronMuPi/PID/hTPCsignalVsP"))->Fill(daug[0].P(), trkDaug1.tpcSignal());
          histos.get<TH2>(HIST("EventTwoTracks/ElectronMuPi/PID/hTPCnSigmaVsP"))->Fill(daug[0].P(), trkDaug1.tpcNSigmaEl());
          if (trkDaug1.hasTOF()) {...}
        }
        if ((countPVGTelectrons == 2) || (countPVGTelectrons == 1 && countPVGTmuons == 1) || (countPVGTelectrons == 1 && countPVGTpions == 1)) {...}
      }
      if (trkDaug2.hasTPC()) {
        histos.get<TH2>(HIST("EventTwoTracks/PID/hTPCsignalVsP"))->Fill(daug[1].P(), trkDaug2.tpcSignal());
        histos.get<TH2>(HIST("EventTwoTracks/PID/hTPCnSigmaElVsP"))->Fill(daug[1].P(), trkDaug1.tpcNSigmaEl());
        histos.get<TH2>(HIST("EventTwoTracks/PID/hTPCnSigmaMuVsP"))->Fill(daug[1].P(), trkDaug1.tpcNSigmaMu());
        histos.get<TH2>(HIST("EventTwoTracks/PID/hTPCnSigmaPiVsP"))->Fill(daug[1].P(), trkDaug1.tpcNSigmaPi());
        histos.get<TH2>(HIST("EventTwoTracks/PID/hTPCnSigmaKaVsP"))->Fill(daug[1].P(), trkDaug1.tpcNSigmaKa());
        histos.get<TH2>(HIST("EventTwoTracks/PID/hTPCnSigmaPrVsP"))->Fill(daug[1].P(), trkDaug1.tpcNSigmaPr());
        if (trkDaug2.hasTOF()) {...}
        if (countPVGTelectrons == 2) {...}
        if ((countPVGTelectrons == 1 && countPVGTmuons == 1) || (countPVGTelectrons == 1 && countPVGTpions == 1)) {
          histos.get<TH2>(HIST("EventTwoTracks/ElectronMuPi/PID/hTPCsignalVsP"))->Fill(daug[1].P(), trkDaug2.tpcSignal());
          histos.get<TH2>(HIST("EventTwoTracks/ElectronMuPi/PID/hTPCnSigmaVsP"))->Fill(daug[1].P(), trkDaug2.tpcNSigmaEl());
          if (trkDaug2.hasTOF()) {...}
        }
        if ((countPVGTelectrons == 2) || (countPVGTelectrons == 1 && countPVGTmuons == 1) || (countPVGTelectrons == 1 && countPVGTpions == 1)) {...}
      }
      if (trkDaug1.hasTPC() && trkDaug2.hasTPC()) {
        if (countPVGTelectrons == 2) {...}
        if (!isMC && ((countPVGTelectrons == 1 && countPVGTmuons == 1) || (countPVGTelectrons == 1 && countPVGTpions == 1))) {
          double electronPt = (enumMyParticle(trackPDG(trkDaug1, cutPID.cutSiTPC, cutPID.cutSiTOF, cutPID.usePIDwTOF, cutPID.useScutTOFinTPC)) == P_ELECTRON) ? daug[0].Pt() : daug[1].Pt();
          double electronPID = (enumMyParticle(trackPDG(trkDaug1, cutPID.cutSiTPC, cutPID.cutSiTOF, cutPID.usePIDwTOF, cutPID.useScutTOFinTPC)) == P_ELECTRON) ? trkDaug1.tpcSignal() : trkDaug2.tpcSignal();
          double electronNsigma = (enumMyParticle(trackPDG(trkDaug1, cutPID.cutSiTPC, cutPID.cutSiTOF, cutPID.usePIDwTOF, cutPID.useScutTOFinTPC)) == P_ELECTRON) ? trkDaug1.tpcNSigmaEl() : trkDaug2.tpcNSigmaEl();
          double electronPiNsigma = (enumMyParticle(trackPDG(trkDaug1, cutPID.cutSiTPC, cutPID.cutSiTOF, cutPID.usePIDwTOF, cutPID.useScutTOFinTPC)) == P_ELECTRON) ? trkDaug1.tpcNSigmaPi() : trkDaug2.tpcNSigmaPi();
          double otherPt = (enumMyParticle(trackPDG(trkDaug2, cutPID.cutSiTPC, cutPID.cutSiTOF, cutPID.usePIDwTOF, cutPID.useScutTOFinTPC)) == P_ELECTRON) ? daug[0].Pt() : daug[1].Pt();
          double otherPID = (enumMyParticle(trackPDG(trkDaug2, cutPID.cutSiTPC, cutPID.cutSiTOF, cutPID.usePIDwTOF, cutPID.useScutTOFinTPC)) == P_ELECTRON) ? trkDaug1.tpcSignal() : trkDaug2.tpcSignal();
          double otherNsigmaMu = (enumMyParticle(trackPDG(trkDaug2, cutPID.cutSiTPC, cutPID.cutSiTOF, cutPID.usePIDwTOF, cutPID.useScutTOFinTPC)) == P_ELECTRON) ? trkDaug1.tpcNSigmaMu() : trkDaug2.tpcNSigmaMu();
          double otherNsigmaPi = (enumMyParticle(trackPDG(trkDaug2, cutPID.cutSiTPC, cutPID.cutSiTOF, cutPID.usePIDwTOF, cutPID.useScutTOFinTPC)) == P_ELECTRON) ? trkDaug1.tpcNSigmaPi() : trkDaug2.tpcNSigmaPi();
          histos.get<TH2>(HIST("EventTwoTracks/ElectronMuPi/PID/hTPCsignalVsEPofE"))->Fill(electronPt, electronPID);
          histos.get<TH2>(HIST("EventTwoTracks/ElectronMuPi/PID/hTPCsignalVsOPofO"))->Fill(otherPt, otherPID);
          histos.get<TH2>(HIST("EventTwoTracks/ElectronMuPi/PID/hTPCnSigmaVsEPofE"))->Fill(electronPt, electronNsigma);
```

Track selection: Two-tracks events, PID selection: non applied.

- ..







Track selection: Two-tracks events, PID selection: Most probable el/μ/π based on nσ^{TPC}

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